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Determining Logistics Ground Support Manpower Requirements for a Reusable Military Launch Vehicle

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DETERMINING LOGISTICS GROUND SUPPORT MANPOWER REQUIREMENTS FOR A REUSABLE MILITARY LAUNCH VEHICLE

THESIS

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Abstract

Successful space-based technologies like satellite imagery and GPS have increased military demand for a rapid-response launch capability. AF Space Command's Operationally Responsive Spacelift program was developed to ensure that the AF has the capability to launch a payload into orbit within hours of a tasking notification, and requires development of a new space launch vehicle. The Reusable Military Launch Vehicle (RMLV) is currently in the design phase. The AF Research Laboratory sponsored development of the MILEPOST simulation model in order to assess the turnaround time, and thus responsiveness, of various design alternatives. The focus of this thesis is to improve the fidelity of the MILEPOST model by assessing the logistics manpower required to support the modeled turnaround activities.

The research determined the appropriate AF organizational structure and manpower requirements for RMLV ground support agencies based on the activities modeled in MILEPOST. This information will be incorporated into the model in future research efforts, resulting in the capability to evaluate RMLV design alternatives based on both turnaround time and workforce requirements.

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To mother, father, and husband

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I. Introduction

In an era of growing uncertainty and rapidly advancing technology, military superiority in space provides a critical asymmetric advantage over our enemies, securing "the ultimate high ground" for our warfighters (Air Force, AFDD 2-2, 2001: vii). Looking toward the future, the Air Force (AF) is seeking to "enhance modern military operations across the spectrum of conflict" (Air Force, AFDD 2-2, 2001: 1) through the continued development of space operations and the incorporation of space capabilities into every aspect of military operations. Specifically, in support of developing space operations, the AF is in the development phase of a Reusable Military Launch Vehicle (RMLV)[1] program that will provide quick-response access to space for the delivery of payloads and other operations.

This chapter will first review the background leading to the development and design requirements for the RMLV, synthesizing national, AF, and AF Space Command (AFSPC) policy into the final requirements defined by the AF for RMLV development. Second, the research problem will be presented along with a definition of logistics support requirements and an explanation of their importance to the RMLV design and development process. Next, research questions will be enumerated to define the scope of

[1] This paper will refer to the vehicle as an RMLV, as the AF's military version of a reusable space-launch vehicle. Other terminology appears within the literature describing similar concepts, including Reusable Launch Vehicle (RLV); Hybrid Launch Vehicle (HLV); and Two-Stage-to-Orbit (TSTO) vehicle.

research. The chapter will conclude by identifying the assumptions and limitations that bound this research effort.

Background

Requirements for the RMLV program were reviewed in national policy, AF doctrine, and AFSPC mission needs, concluding with the RMLV requirements defined by the Program Research and Development announcement to potential bidders in 2005. This background provides a comprehensive overview of the origins and intent of the concept of developing the RMLV, clearly defining the mission and required capabilities of this future vehicle.

National Space Policy.

The importance of space operations has been recently reinforced in the President's National Space Policy, delivered August 31, 2006. This policy reiterated the vital nature of space operations to national interests and established the intent of the United States to:

> preserve its rights, capabilities, and freedom of action in space; dissuade or deter others from either impeding those rights or developing capabilities intended to do so; take those actions necessary to protect its space capabilities; respond to interference; and deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests (President, 2006: 1).

In support of this policy, the Secretary of Defense is tasked to:

> [m]aintain the capabilities to execute the space support, force enhancement, space control, and force application missions;…[p]rovide, as launch agent for both the defense and intelligence sectors, reliable, affordable, and timely space access for national security purposes;…[and p]rovide space capabilities to support continuous, global strategic and tactical warning as well as multi-layered and integrated missile defenses (President, 2006: 4).

National space policy, then, as a source for the basic design goals of the RMLV, defines the requirement for a dependable, cost-effective, and responsive space launch program capable of performing deterrence, protection, response to interference, and denial of access missions in support of national security. Another source that defines the expectation of capabilities for an RMLV is AF doctrine concerning space operations.

AF Space Operations Doctrine.

AF doctrine regarding space operations "views air, space, and information as key ingredients for dominating the battlespace and ensuring superiority" (Air Force, AFDD 2-2, 2001: 1); that is, air and space operations have a synergistic relationship in the military environment. Indeed, since the successful use of GPS in Desert Storm, space-based capabilities have been recognized as providing the "ultimate high ground of US military operations" (Air Force, AFDD 2-2, 2001: vii). As a result, space doctrine has been developed from the existing model of air power doctrine, defining how space operations support each of the "principles of war, tenets of air and space power, [and] Air Force functions" (Air Force, AFDD 2-2, 2001: 6).

The nine principles of war and seven tenets of air and space power apply to space assets in a similar manner as they are applied to airpower assets, while recognizing the unique characteristics of space capabilities. For instance, under the second tenet of air and space power, space capabilities should be employed in a manner to maximize flexibility and versatility. Most satellites are not flexible by nature in their abilities to be quickly deployed, maneuvered, or adjusted; however, they provide increased flexibility of communications to ground forces (Air Force, AFDD 2-2, 2001: 7). Similarly, each of the principles and tenets developed for the use of airpower is adapted to provide a guide for the employment of space capabilities.

There are 16 AF functions that space capabilities are aligned against, sometimes in a primary role, and sometimes as a supporting capability. These functions include counterspace (offensive and defensive), spacelift, counterinformation, command and control, intelligence, surveillance, reconnaissance, navigation and timing, weather services, combat search and rescue, counterair, counterland, countersea, special operations, strategic attack, and airlift and air refueling. Of these functions, this paper is primarily concerned with spacelift, which "projects power by delivering satellites, payloads, and materiel to or through space" (Air Force, AFDD 2-2, 2001: 11). The AF defines three strategies and one emerging strategy for spacelift:

1. Launch to deploy achieves a satellite system's designed initial operational capability. This strategy uses a launch-on-schedule approach where launches are planned in advance and executed in accordance with the current launch schedule.
2. Launch to sustain replaces satellites nearing the end of their useful life, predicted to fail, or that have failed.
3. Launch to augment increases operational capability above the designed operational capability in response to war, crisis, or contingency.
4. Launch to operate is an emerging strategy to increase the useful life of space assets through scheduled or on-demand launches providing space support such as refueling or repair (Air Force, AFDD 2-2, 2001: 11).

According to this doctrine, the AF seeks to realize a spacelift platform with all-weather capability and responsiveness on the order of days or hours (Air Force, AFDD 2-2, 2001: 11).

AF doctrine, then, as a source for the basic design goals of the RMLV, defines the requirement for an all-weather launch-vehicle capable of performing deployment, sustainment, augmentation, and operation missions within days or hours of initial tasking. A third source for design requirements is the Operationally Responsive Spacelift program directed by AFSPC.

Operationally Responsive Spacelift.

In support of national space policy and AF doctrine, AFSPC has developed an ORS program to ensure that the AF has the capability to "rapidly put payloads into orbit and maneuver spacecraft to any point in earth-centered space, and to logistically support them on orbit or return them to earth" (AFSPC, 2001: 1). ORS is cited as the "key enabler for conducting the full spectrum of military operations in space and for achieving space superiority" (AFSPC, 2001: 2). The ORS mission, as defined by AFSPC, requires four key capabilities:

1) Rapid satellite deployment in support of crises and combat operations;
2) Peacetime launch for sustainment of satellite constellations;
3) "Recoverable, rapid-response transport to, through, and from space;"
4) Integrated mission planning to enable quick-response execution (AFSPC, 2001: 2).

The following characteristics should be part of any system developed in support of ORS: responsive, maneuverable, operable, economical, survivable, interoperable and flexible (AFSPC, 2001: 2). Essentially, any vehicle supporting the ORS mission must be able to launch within hours in response to a mission tasking; maneuver among orbits; be reliable, supportable, and maintainable enough to consistently meet mission requirements; be cost-effective; be hardened against a threat environment; be able to be integrated into a joint and allied operating environment; and be able to deliver a variety of payloads to multiple theaters (AFSPC, 2001: 2).

These requirements apply to the vehicle as a whole. For the purposes of this thesis, the RMLV is primarily concerned with the first stage of the vehicle, which is reusable and will be recovered and re-launched, driving turnaround time capabilities. As a result, we will not be addressing the orbital capabilities required of the vehicle.

The ORS program, then, as a source for the basic design goals of the RMLV, defines the requirement for a reliable, maintainable, cost-effective vehicle that can be launched within hours of tasking in support of wartime or peacetime operations. Given the consistency of launch vehicle requirements throughout national, AF, and Space Command policy, the RMLV concept has been developing as described in the following section to support mission requirements.

Reusable Military Launch Vehicles.

In 2004, the AF Requirements for Operational Capabilities Council approved the Analysis of Alternatives (AoA) for ORS, establishing the Hybrid Launch Vehicle (HLV) as the standard for AF reusable launch vehicle acquisition. The AoA evaluated a wide range of current and developmental space launch options, including Evolved Expendable Launch Vehicles (EELVs) like the Delta 4 and Atlas 5 currently in use; new Expendable Launch Vehicles with three solid stages or two liquid stages; fully reusable Two-Stage-to-Orbit vehicles with a variety of fuel alternatives; and HLVs with reusable boosters and liquid or solid expendable upper stages. "The HLV concept was conceived specifically to [provide] affordability, responsiveness, simplicity of operations, and reliability for a wide range of payload classes" (Hybrid Launch Vehicle, 2005) and, indeed, the AoA determined that the HLV provided the best projected combination of low development cost, low per-launch cost, potential 2-4 day turnaround time, and low technical risk (Hickman, 2005: 7). As a result, the Statement of Objectives (SOO) and the Program Research and Development Announcement (PRDA) for the RMLV have specified an HLV with the operational requirements outlined in Table 1 as the AF platform for Operationally Responsive Spacelift.

Table 1. RMLV Performance Requirements (HQ SMC, SOO, 2005: 3)

Operational Parameter	Threshold	Objective
First Stage Turn -Around Time	48 hours	24 hours
HLV OS Recurring Flight Cost	1/3 current EELV -M launch costs	1/6 current EELV -M launch costs
HLV OS Initial Production Size	6 Operational First Stages	6 Operational First Stages
First Stage Return to Base (RTB) – Nominal Mission	Required	Required
First Stage RTB – Intact Abort	50%*	90%*
Blue Suit Operators	Blue Suit & Contractor	Blue Suit
HLV OS Upper Stages Production Costs	$10M per unit	$5M per unit
Use of Foreign Designed Critical Components	Domestic Production Required	No Foreign Designed Components

In summary, the current expectation is a fleet of six reusable RMLV boosters, each with a 24-hour turnaround time. Conceptually, the mission sequence shown in Figure 1 has been envisioned for RMLV Operations:

Figure 1. Pictorial Representation of RMLV Operations
(HQ SMC, HLV Photos, 2005: 3, 6, 8)

In general, a vertical-launch, horizontal-landing vehicle is envisioned, but the Industry Day instructions to bidders allow for any launch and landing configuration that meets the operational parameters outlined in Table 1 (HQ SMC Q&A, 2005: 1st Set, Question 21). Thrust and lift capability requirements are also outlined in the Statement of Objectives, but designers are free to use any engine and propellant combinations they like to achieve those objectives in an initial demonstrator, with the limitation that the final RMLV should use domestic components as indicated in the operational parameters (HQ SMC Q&A, 2005: 1st Set, Question 32).

As with any developmental platform, particularly one using advanced technologies, several different design alternatives may be proposed to meet the objectives outlined in this section. These alternatives will be evaluated based on technical, risk, and cost/price criteria (HQ SMC PRDA, 2005: J). The technical evaluation is based on the bidders' ability to meet the requirements outlined in the Statement of Objectives; however, the ability to meet these requirements is based on more than simply the technical composition of the vehicle. Identifying the logistics support required by a future fleet of RMLVs is a critical aspect of ensuring the best vehicle to support national and Air Force spacelift objectives.

Problem

The ability to meet turnaround time and recurring flight cost goals is heavily influenced by a platform's logistics support requirements. Lessons learned from the Space Shuttle indicate that there is room for improvement in designing for "operability, supportability, and dependability" of future launch vehicles (McCleskey, 2005: 131). The AF requires that ORS be "completely supportable within DoD maintenance principles and emphasize lean, responsive, and economical support systems" (AFSPC, 2001: 5.1.2). Any systems developed in support of ORS are expected to utilize AF standard logistics support and maintenance procedures in order to meet mission requirements. "Reliability, maintainability, supportability, and disposal considerations must be emphasized to meet readiness and life cycle cost objectives" (AFSPC, 2001: 5.1.2). Clearly, logistics support is an important factor in the mission success of the RMLV, and it is a factor that can begin to be evaluated even in this early stage of development.

"Logistics requirements for launch systems are largely driven by the choices made during the design process and decisions about how the design will be supported in its operating environment" (Morris, 1997: 1). In order to support the assessment of design impact on turnaround times, AFIT graduate researchers developed MILEPOST, a discrete-event simulation tool that models the ground support process from an RMLV landing to its next launch. Ground support operations, or regeneration activities, include vehicle recovery, maintenance, and pre-launch activities, and were developed using a synthesis of similar activities required for aircraft, EELVs, Intercontinental Ballistic Missiles (ICBMs), and the Space Shuttle to provide the most comprehensive and accurate model of possible RMLV turnaround operations (Stiegelmeier, 2006; Pope, 2006; Martindale, 2006). The development and characteristics of the MILEPOST model are discussed in greater detail in Chapter III, Introduction to MILEPOST. The primary benefit of this model, however, is that it allows users to input certain design features, such as number of engines, type of propellant, and integration sequence, and receive an output of average turnaround time based on the ground support actions required for their design. At the same time, computer simulation models are being used to map the operation cycle of the vehicle from launch to landing using a continuous simulation model developed by the AF Research Laboratory (AFRL). The intent of these models is to introduce logistics support considerations into RMLV operations in the design phase.

In its current form, MILEPOST assumes infinite resource availability for ground support actions. Like other models, the end goal of MILEPOST is to assess the turnaround time and logistics support requirements for a proposed RMLV; also like other models, MILEPOST is "predicated on the assumption that these requirements should be based on the maintenance actions generated by each mission" (Morris, 1997: 2). This research will seek to improve the fidelity of the model by assessing the manpower resources required to perform the ground maintenance actions necessary to meet the operational requirements for a fleet of RMLVs.

Research Objective

The objective of this research is to develop an estimate of the logistics workforce required to support the regeneration activities identified in MILEPOST. This workforce will be based on AF standards for organization and manpower assignment and designed to meet operational requirements as defined by ORS objectives and captured by the MILEPOST model. The following research questions provide a framework for the research and a step-by-step process for assessing the logistics manpower support requirements for a fleet or RMLVs.

1. How do current AF Specialty Codes (AFSCs) support the performance of the ground support tasks identified in MILEPOST?

2. What AF organizational structure is most appropriate for RMLV logistics and maintenance support?

3. What are the projected total AF manpower requirements to support RMLV regeneration?

4. What will the life cycle cost and training ramifications be as the RMLV platform enters the AF inventory?

Following a literature review, an introduction to the MILEPOST model, and a description of research methodology, each of these questions was addressed in turn to achieve the final objective of capturing the logistics workforce implications of the RMLV program.

Assumptions and Limitations

Based on the RMLV requirements outlined above in the PRDA, this research assumed an RMLV fleet size of six vehicles, each with a reusable first stage booster and expendable second-stage rockets. The six boosters formed the basis of the logistics support requirements assessed in this research.

Additionally, although not strictly required by the PRDA, this research assumed that the vehicle would take off vertically and land horizontally from either Cape Canaveral Air Force Station or Vandenberg Air Force Base. For the purposes of assessing the organizational structure and manpower requirements, a blue-suit workforce was assumed. This provides an analysis of the capability of the AF to provide the required support; portions of this support may, at a later time, be awarded to contractors or government civilians as deemed appropriate by the RMLV user.

This assessment was also limited to supporting the regeneration tasks identified in MILEPOST. Other support functions may be required based on the final RMLV design characteristics; however, those tasks identified in MILEPOST have been validated by experts in the field as representative of the significant design alternatives under consideration, as is further discussed in Chapter III, Introduction to MILEPOST.

Finally, in order to establish the appropriate organizational structure and thereby project total manpower requirements, an RMLV mission statement must be assumed. Based upon the objectives and requirements defined by National Space Policy, AF Space Operations Doctrine, and AF Space Command Policy, the RMLV mission was defined in the following manner: The mission of the RMLV fleet is to preserve the nation's freedom of operations in space by providing dependable, responsive spacelift capability to deliver payloads supporting deployment, sustainment, augmentation, and operations missions within hours or days of initial tasking.

Summary

This chapter has provided a review of the background concerning ORS and the development of requirements for a reusable launch vehicle, as well as a definition of the problem facing RMLV development regarding the assessment of logistics support requirements. A definition of the research scope and process has been presented for identifying the logistics manpower required to support a fleet of RMLVs. Assumptions and limitations, including the RMLV mission statement, have been addressed that will provide the foundation for reaching the research objective. The next chapter will present a review of the literature relevant to each of the research questions, investigating AF policy and information from aircraft, EELVs, missiles, and NASA to provide the most comprehensive framework for developing the RMLV logistics workforce.

II. Literature Review

A great deal of literature, from both commercial and government sources, exists concerning logistics support requirements for aerospace platforms. Literature was reviewed to first provide a solid justification for this line of research, and then to address each of the research questions in turn. The progression of this chapter follows the investigation of the body of knowledge concerning:

1. The importance of logistics manpower considerations in aerospace vehicle design;
2. The definition of "logistics support" manpower as it will be utilized in this thesis, and the correlation to current AFSCs;
3. Organizational structure;
4. The process of determining manpower requirements for aerospace vehicles;
5. And life cycle cost considerations for aerospace platforms.

The purpose of this review was to establish a clear direction for the research effort of each investigative question, culminating in an overall estimate of the RMLV logistics workforce.

Vehicle Design and Logistics Manpower Considerations

As discussed in Chapter I, Introduction, the objective of this research was to develop an estimate of the logistics manpower required to support the regeneration activities identified in MILEPOST for an RMLV. Past experience and current engineering disciplines suggest that adopting a comprehensive view of systems comprising an aerospace platform early in and throughout the design process is critical to its success over the span of its life cycle.

Systems Engineering and Vehicle Design.

Systems Engineering is defined by the International Council on Systems Engineering (INCOSE) as “an interdisciplinary approach and means to enable the realization of successful systems” (What is, 2006). It can be generically applied to any system under development, and focuses on “defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation” while considering, throughout the process, all operations, cost and schedule, performance, training and support, test, and disposal aspects of the finished system (What is, 2006). As an organization, INCOSE was originally formed in response to the need for “*qualified* engineers…who could think in terms of a total system…rather than just a specific discipline” (Genesis, 2006). The need for a system-wide approach had, in turn, been generated by the increasing complexity of systems under development and the extensive integration requirements of system components.

This trend holds particularly true in the aerospace industry as technologies like Integrated Vehicle Health Management (IVHM) “become increasingly important to fighters and bombers, commercial and military transports, rotorcraft, spacecraft, and satellites” and demand input regarding the “health of the entire vehicle including avionics, propulsion, actuators, environmental control, electrical components, and structures” (Ofsthun, 2002: 21). In fact, the increasing interest in IVHM for developing platforms reinforces the systems engineering principles described above as IVHM design “must be part of the overall design process and viewed as a system engineering discipline” if it is to overcome the limitations currently imposed by retrofitting IVHM systems into existing platforms at a component level and achieve the full capability of total vehicle health management (Barrientos, 2005: 3).

Specifically as regards spacecraft, the complexity of the systems under development has led to the incorporation of systems engineering principles as a fundamental aspect of spacecraft design. Space systems engineering is defined as “the art and science of developing an operable system capable of meeting mission requirements within imposed constraints including (but not restricted to) mass, cost, and schedule” (Griffin, 2004: 2). In recognition of the importance of Systems Engineering in aerospace design, NASA formally adopted Systems Engineering as an organization-wide standard in 1989, developing a training program and accompanying handbook to assist engineers in applying the practice to NASA projects (Shishko, 2006: ix).

In addition to the wealth of support for systems engineering principles in the commercial sector and at NASA, the Department of Defense has established them as part of its acquisition process. “DoD policy and guidance recognize the importance of and introduce the application of a systems engineering approach in achieving an integrated, balanced system solution” (Defense Acquisition Guidebook, 2006: 4.0). The Defense Department’s goal is to apply systems engineering processes early in concept definition and throughout the system life cycle in order to develop reliable and maintainable systems that optimize performance while minimizing total ownership costs (Defense Acquisition Guidebook, 2006: 4.0-4.1).

Logistics Considerations and Systems Engineering.

In short, systems engineering will be critical to the RMLV design process; and logistics considerations are critical to sound systems engineering processes. The ability to achieve operationally effective systems at an affordable cost is reliant upon many factors, represented below. Of these, logistics considerations directly address the Maintainability, Operations, Maintenance, and Logistics components of the Defense Department's overall goal of affordable operational effectiveness for developmental systems, depicted in Figure 2.

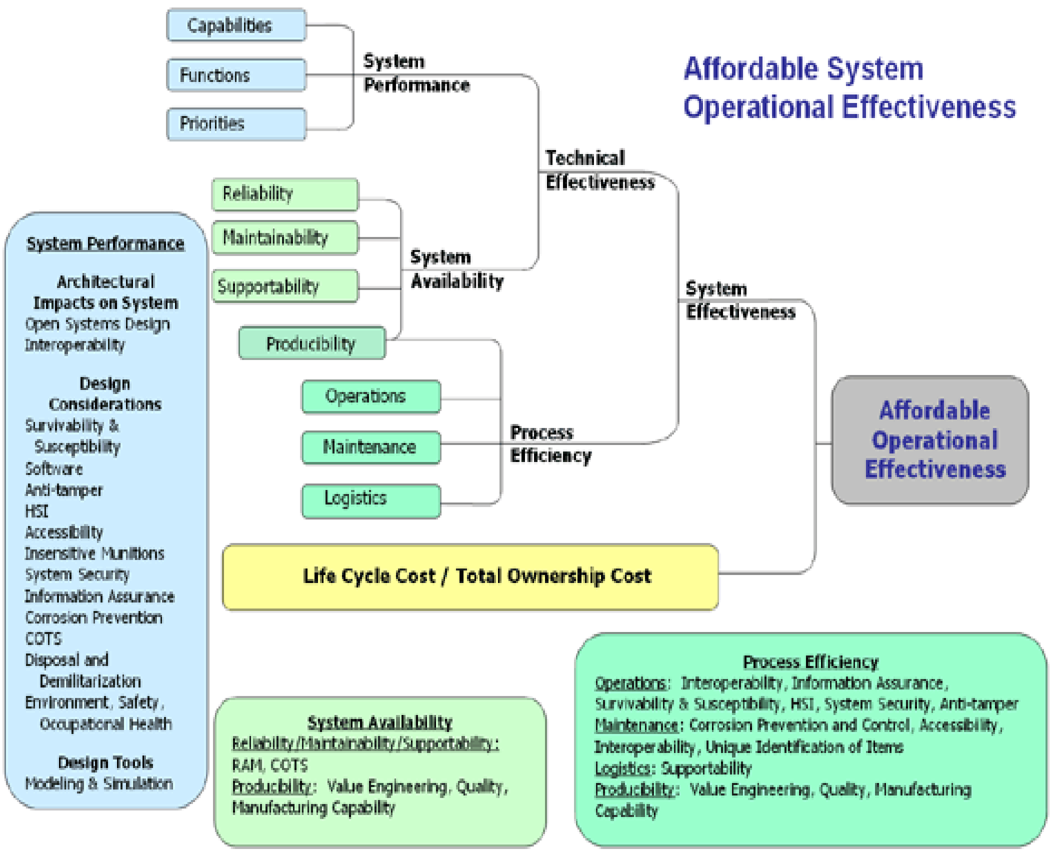

Figure 2. Achieving Affordable System Operational Effectiveness
(Defense Acquisition Guidebook, 2006: 4.4)

Previous AF design efforts like the B-2 stealth bomber have recognized the importance of logistics considerations in systems engineering efforts.

> A key aspect of the implementation of the B-2 systems engineering process was the integration of the S[ystem] P[rogram] O[ffice] requirement's team with the contractor's design team, including manufacturing, Quality Assurance, and logistics functionals into a cohesive program (Griffin, 2006: 51).

Further, changes in the acquisition process like incremental or spiral development strategies have blurred the chronological boundaries between design, development, deployment, and sustainment phases of system development. The Department of Defense now recognizes that:

> Effective sustainment of weapons systems begins with the design and development of reliable and maintainable systems through the continuous application of a robust systems engineering methodology that focuses on total system performance. L[ife] C[ycle] L[ogistics] should be considered early and iteratively in the design process, and life cycle <u>sustainment</u> requirements are an integral part of the systems engineering process (Defense Acquisition Guidebook, 2006: 5.2).

While systems engineering incorporates a wide range of disciplines, it is clear that logistics considerations are an important part of the process.

Additionally, NASA attributes the "primary influence in the high costs of current launch systems…[to] the operations, maintenance and infrastructure portion of the program's total life cycle costs" (Fox, 2001: 439). While exact figures vary, it is well-established that operation and maintenance costs, which can be generally categorized as logistics support, form a significant factor in the total life cycle cost considerations for an aerospace vehicle. In fact, the Defense Acquisition Guide, which defines Operating and Support Costs as "the costs…of personnel, equipment, supplies, software, and services associated with operating, modifying, maintaining, supplying, training, and supporting a system in the DoD inventory" (Defense Acquisition Guidebook, 2006: 3.1.3), depicts them as the largest portion of total life cycle costs, as shown in Figure 3.

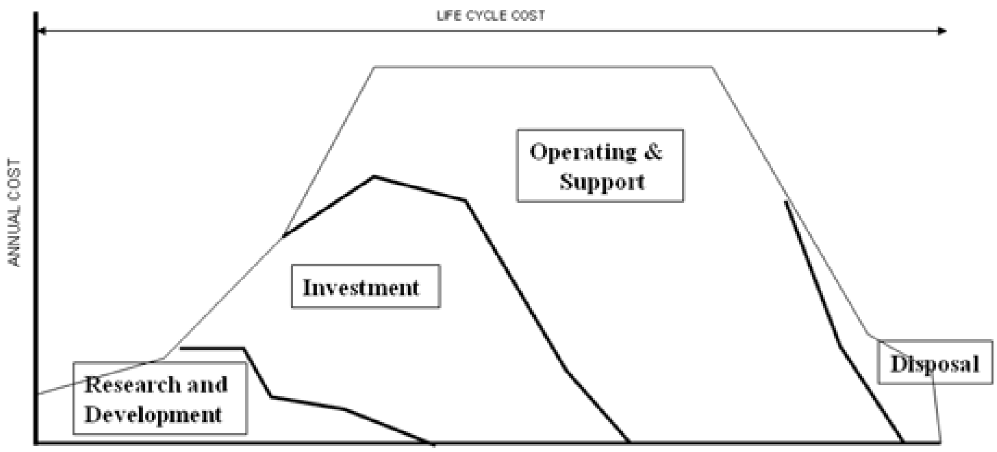

Figure 3. Life-Cycle Cost Components (Defense Acquisition Guidebook, 2006: 3.1.2)

Given the significant role of logistics elements in effective systems engineering principles as well as their contribution to total system cost, it can be concluded that logistics considerations will be critical throughout the RMLV design process.

Manpower Estimates and Logistics Considerations.

Logistics considerations, as a general category, include many elements addressed in the previous sections, including maintenance, supplies, and personnel. The personnel element is the primary focus of this thesis, and is specifically targeted by the Department of Defense as a critical component of the affordability considerations of the system acquisition process. Program affordability "is part of the Joint Capabilities Integration and Development System analysis process, which balances cost versus performance in establishing key performance parameters" before a project is even approved for initiation (Defense Acquisition Guidebook, 2006: 3.2.1). Assessing program affordability requires demonstrating that the "program's projected funding and manpower requirements are realistic and achievable" within the context of the DoD component's corporate long-term goals (Defense Acquisition Guidebook, 2006: 3.2.2).

> For Major Defense Acquisition Programs, 10 U.S.C. 2434 requires the Secretary of Defense to consider the estimate of the personnel required to operate, maintain, support, and provide system-related training, in advance of approval of the development, or production and deployment of the system (Defense Acquisition Guidebook, 2006: 3.5).

NASA, likewise, recognizes the importance of the role of manpower considerations within logistics planning. Having identified Integrated Logistics Support as one of eight engineering specialties within the overall Systems Engineering Process (Shisko, 2006: 91), NASA goes on to specify Human Resources and Personnel Planning as one of the nine elements that fall within the responsibilities of the Integrated Logistics engineers (Shisko, 2006: 99). Specifically, these activities include "actions required to determine the best skills-mix, considering current and future operator, maintenance, engineering, and administrative personnel costs" (Shisko, 2006: 99).

In summary, professional and trade-specific literature identify systems engineering as a critical aspect of aerospace vehicle design, logistics considerations as a critical aspect of systems engineering, and manpower considerations as a critical aspect of logistics. This thesis, therefore, will proceed on the conclusion that determining the logistics manpower requirements for supporting an RMLV fleet is a valuable contribution to the current design process.

Defining Logistics Support Manpower

In order to address the first investigative question, regarding how current AFSCs support the performance of the ground support tasks identified in MILEPOST, a definition is required for ground support and logistics support and their relationship to the current AFSC structure.

Defining Logistics Support and Ground Support.

Logistics, as officially defined by the Council of Supply Chain Management Professionals (CSCMP), is a broad concept that includes the "process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services" (Supply Chain, 2006). Logistics Management is defined as "that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements" (Supply Chain, 2006). These generic, commercial definitions concentrate on the market aspects of providing goods and services in response to requirements.

Unfortunately, by focusing on transportation and storage of finished goods or services, these definitions shed little light on the role of logistics in development and deployment of a launch vehicle. In the military arena, however, logistics is more specifically defined as:

> those aspects of military operations that deal with: a. design and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposition of materiel; b. movement, evacuation, and hospitalization of personnel; c. acquisition or construction, maintenance, operation, and disposition of facilities; and d. acquisition or furnishing of services (DoD, JP-1, 2006).

As relates to the RMLV, the logistics arena would be defined under the construct of "materiel" as dealing with all aspects of its life cycle from design to disposition.

The airport concept of ground support provides further insight into the types of activities that will be the focus of this thesis. Within the air transportation system, ground time "includes all processes and activities from wheels-on to wheels-off" (Andersson, 2006: 1). These processes and activities are typically subcontracted to an airline, airport, or handling agent "to handle the many needs of passenger aircraft" including cabin service, catering, ramp service, maintenance and engineering service, and field operation service (Aircraft, 2007). Subcontracted agencies, such as GAT Airline Ground Support and Airport Terminal Services (ATS) further define the scope of ground support within the specific services that they provide: cargo management, janitorial, cabin grooming, ground support equipment maintenance, facilities maintenance, Skycap and porter service, passenger check-in and ticketing, passenger boarding, VIP lounge staffing, baggage services and lost and found, aircraft loading and unloading, aircraft marshalling, aircraft pushback, aircraft fueling, aircraft deicing, warehouse receiving and delivery functions, document processing, and fuel farm management (Services, 2006; What We Do: Service, 2006). While many of these functions are not directly applicable to the RMLV mission as currently defined, they do establish the comprehensive nature of ground support activities.

In previous AFIT research efforts, the MILEPOST model was developed to identify the regeneration activities required between subsequent RMLV launches. These activities were broken into three phases—post-landing recovery, maintenance, and pre-launch—and included such processes as towing, inspection and repair, fueling, and payload integration (Martindale, 2006; Pope, 2006; Stiegelmeier, 2006). Thus, as defined by MILEPOST, the activities that require manpower resources for support encompass all actions from touch-down to subsequent launch, and incorporate the maintenance aspect of military logistics with some handling aspects of ground support. For the purpose of this thesis, logistics support, ground support, and regeneration support will be used interchangeably to indicate those activities identified in MILEPOST as being necessary to recover and subsequently launch an RMLV. These activities will be covered in greater detail in Chapter III, Introduction to MILEPOST.

Logistics Support AFSCs.

Having determined the range of RMLV support activities that will be addressed in this thesis, the next portion of the research question addressed the capability of the current AFSC structure to support those activities. AFSCs are governed by AF Officer and Enlisted Classification Directories, which are updated and published semi-annually (Air Force, AFMAN 36-2101, 2006: 55). Of these available AFSCs, only certain classifications are considered Logisticians, who would directly be responsible for performing the logistics support activities defined in the previous section.

The AF professional association for logistics officers, the Logistics Officers Association, defines logisticians as “key aircraft and munitions maintenance, logistics readiness, transportation, supply, contracting and logistics plans decision-makers” (Matthews, 2006). The headquarters component for logistics support within the AF is the A4/7 Directorate, Logistics, Installations, and Mission Support, and encompasses six sub-directorates including the offices of Transformation, Maintenance, Resource Integration, Logistics Readiness, the Civil Engineer, and Security Forces and Force Protection (Headquarters Air Force, 2006). Within these organizations, the offices of Transformation and Resource Integration address strategic-level considerations for long-range planning (Headquarters Air Force, 2006). The Directorates of Maintenance, Logistics Readiness, Civil Engineer, and Security Forces oversee functions that directly relate to aerospace platform operation and infrastructure (Headquarters Air Force, 2006). Since the focus of this research effort is on those activities directly supporting the RMLV from landing to subsequent takeoff, Civil Engineer and Security Forces personnel performing infrastructure support will not be addressed

Thus, within the established AFSC structure, Maintenance and Logistics Readiness AFSCs will provide the basis for consideration for the RMLV logistics support workforce. The specific AFSCs within these functions will be addressed in detail in Chapter V, Analysis of Required Technical Expertise.

Organizational Structure

In order to accurately determine the logistics workforce characteristics for the RMLV, it is necessary to determine the manner in which the required technical experts will be organized.

Organization Theory.

A formal organization arises out of the need to coordinate a group of people toward the "explicit purpose of achieving certain goals" (Blau, 2004: 1). The organization will "formulate procedures that govern the relations among the members…and the duties each is expected to perform" and then tend to "assume an identity of its own" which enables it to "persist for several generations, not without change but without losing [its] fundamental identity as [a] distinct unit" (Blau, 2004: 1). If organizations will arise naturally out of the need to accomplish certain tasks, and if they will continue to support those tasks even as members and structures change, the original definition of the structure is of great interest to the successful performance of the task over time.

Organizational structure "describes the division of work and the division of authority found in any organization" (Andersen, 2002: 344). Organizations address division of work and authority in a variety of structures, each of which manifest varying degrees of specialization, centralization, and formalization.

Specialization.

Specialization, or complexity, describes the number, type, and location of specialties or departments within an organization (Andersen, 2002: 344). The grouping of jobs, professions, and specialties into departments or workcenters is a critical aspect of forming an organization, and one of the most difficult aspects of this managerial decision is "whether to group activities primarily by product or by function" (Walker, 2005: 208). Product-oriented departments will incorporate all of the functional specialists needed for an individual product line while function-oriented departments will be composed of a single functional specialty supporting all product lines (Walker, 2005: 208). This decision is a tradeoff, and the mission of the organization will play a role in determining which type of structure will provide the greatest overall benefit, and may result in the utilization of a mixed approach to address different activities within the organization. For example, cross-functional (product-oriented) teams may be formed for certain projects that require a higher degree of coordination, while functional departments are sufficient for the development of standard products (Walker, 2005: 218). In general, functional organizations are appropriate when tasks are routine and repetitive, integration can be achieved through a master plan, and conflict can be resolved through the established management hierarchy (Walker, 2005: 217). Product organization is more appropriate for tasks "of a problem-solving nature…especially…where there is a need for tight integration among specialists" (Walker, 2005: 217). While RMLV development would be most appropriately supported by a product-oriented organization, the logistics ground support of the operational RMLV will most likely require a hybrid structure due to the repetitive nature of certain ground processes and the high degree of coordination required by activities like scheduling and quality control.

Centralization.

Centralization (or decentralization) describes the organizational location of decision-making capabilities. An organization is highly centralized when decision-making authority rests only at high levels of management; conversely, an organization is decentralized when decision-making authority is granted at the lowest possible hierarchical levels (Andersen, 2002: 345). Decentralized decision-making, which includes the popular concept of empowerment, is often considered to reflect an "organization's interest in employee-maintenance issues" and takes advantage of the capabilities of lower-level managers and employees (Osborn, 1980: 300). Certainly, decentralization allows "each administrative unit [to] deal efficiently with its own sector" (March, 1993: 230), freeing upper level management to address more global corporate concerns.

However, there is a price to decentralization, one that has been particularly noted within NASA as a consistent contributor to inefficiencies and even disasters in major programs. NASA's ten field centers have evolved into autonomous agencies, as reduced budgets have driven them to broaden competencies, form alliances with

Congressional delegations, and lobby for projects outside their traditional functional specialties in order to assure individual survival (Levine, 1992: 199). The fragmented management structure has been identified as a contributing cause to the Challenger disaster, a source of serious inefficiencies during Space Station program development, and a compounding factor in the oversight that led to the inoperable primary mirror on the Hubble telescope (Levine, 1992: 201). In the case of the Challenger, program managers for individual elements were overly concerned with accountability to their respective field centers, so that internal flight safety problems were not properly routed through the established Shuttle management system. The Space Station program began with 107 missions, as each of the four field centers involved submitted individual requirements, and no centralized review process was established to coordinate them with one another or with NASA capabilities. Finally, the initial measurement error that resulted in the Hubble mirror flaw was never double-checked throughout the course of development, in part due to a lack of funding; however, the other five Hubble instruments were protected from such detrimental cost-saving measures by independent principal investigators, based outside of NASA in universities, while NASA had sole responsibility for the mirrors (Levine, 1992: 201). It is clear from these examples that reduced budgets have led to autonomy and competition among the NASA field centers, with damaging effects on key programs. The decentralized system that has developed is not conducive to effective program management for such large-scale, complex projects as NASA typically handles. It follows that centralization will be a critical issue during the development of the RMLV; as well, within the logistics support organization for the operational RMLV, careful consideration of the degree of centralization will be critical to launch mission success.

Formalization.

Formalization describes the degree of standardization of tasks and procedures within the organization (Andersen, 2002: 344). Bureaucracies are typically associated with a high degree of formalization, and have been criticized for their inflexibility and tendency toward mediocrity (Osborn, 1980: 276). Large companies, however, typically benefit from formalization, which allows them to ensure consistency throughout the organization (Osborn, 1980: 339).

The benefits of formalizing organizational procedures can be identified in specific arenas within aerospace organizations. For example, the adoption of a robust Quality Management System like the AS9100 aerospace standard can "stabilize and standardize" organizations in an industry in which perceived reliability is critical and, when coupled with consistent adaptation to external market changes, can lead to sustainable organizational growth over time (West, 2005: 80-82). In addition, the importance of learning from successes as well as mistakes in aerospace ventures has led NASA to adopt a formalized learning process, patterned after the military After Action Review (AAR) system (Rogers, 2006: 2). By formalizing the procedures for reviewing and assessing activities at multiple stages in project development, the Goddard Space Flight Center hopes to support agency-wide improvements in learning and knowledge management to ensure future mission success (Rogers, 2006: 7).

Beyond specific organizational benefits, however, the aerospace industry is required to conform to standardized requirements for the safety of its customers and the general public. The Federal Aviation Administration, whose mission is to provide the "safest, most efficient aerospace system in the world," formalizes the tasks and procedures associated with aerospace activities by administering certification requirements for aircraft, airports and spaceports, pilots, and aircraft mechanics; operating a standardized air traffic control system for civil and military aircraft; and regulating noise and environmental effects of air traffic (What we do, 2007). As such, a high degree of formalization in operational activities is established as an aerospace industry standard.

AF Policy.

The RMLV is envisioned as an AF asset; therefore, the suitability of AF organizational structure policy to RMLV logistics support will be addressed next.

<u>Specialization.</u>

One of the principles of AF organization is Functional Grouping, in which personnel that form a "logical, separable activity" report to a single supervisor (Air Force, AFI 38-101, 2006: 6). These functional activities are primarily identified by an AF Specialty Code (AFSC), the "basic grouping of positions requiring similar skills and qualifications" (Air Force, AFMAN 36-2101, 2006: 52). However, a Squadron, the AF's most basic organizational unit, may be "either a mission unit, such as an operational flying squadron, or a functional unit, such as a civil engineer, security forces, or maintenance squadron" (Air Force, AFI 38-101, 2006: 12). As such, the AF is a hybrid organization in which departments may be aligned around missions (products) or functions depending upon the operational requirements.

Specifically within the logistics community, the hybrid nature of the organization continues to apply. Within a Maintenance Group, the Maintenance Squadron (MXS) (conducting backshop repair operations) is typically aligned functionally, consisting of "personnel from various AFSCs organized into flights" like propulsion, avionics, and fabrication (Air Force, AFI 21-101, 2006: 98). However, the Aircraft Maintenance Squadrons (AMXS) (conducting flightline operations) and Maintenance Operations Squadron (MOS) may include many different functional specialists performing cross-functional activities like quality assurance, flightline expediting, and debriefing (Air Force, AFI 21-101, 2006: 70-166). For example, the Specialist section within the AMXS is responsible for:

> troubleshooting, on-equipment repairs, component removal and replacement, aircraft avionics systems classified item management, and aircraft ground handling, servicing, and cleaning…[and] may include avionics, propulsion, hydraulics, and electro/environmental technicians (Air Force, AFI 21-101, 2006: 78).

The Logistics Readiness Squadron is also organized primarily in a hybrid manner, with Materiel Management, Traffic Management, Vehicle Management, and Fuels Management Flights organized functionally by AFSC, while Readiness and Management & Systems Flights perform cross-functional duties and are manned by a variety of AFSCs (Air Mobility Command, AMCMD 716, 2004: 1).

As regards the RMLV, this hybrid organizational structure provides a balance between the benefits of functional organization for repetitive tasks like engine maintenance or wheel and tire repair (MXS functions) and the advantage of cross-functional teams to address objectives like quality assurance and expedited flightline operations (MOS and AMXS functions).

Centralization.

Decentralization is established as a key characteristic of AF organizations, so that "lower echelons can achieve objectives without needing continuous control from above" (Air Force, AFPD 38-1, 1996: 1). However, Unambiguous Command is an equally important characteristic, in which organizational structure provides a "clear chain-of-command running from the President to the most junior airman" (Air Force, AFPD 38-1, 1996: 1). Essentially, the AF organization is tasked to strike a balance between empowerment of lower-level managers for operational decision-making and a centralized management structure for oversight and conflict resolution. This balanced approach provides exactly the type of support structure that can maximize the benefits of decentralization and avoid the consequences of fragmentation experienced at NASA.

Formalization.

Another key characteristic of AF organizations is Standardization, which stipulates that organizations "with like responsibilities should have similar organizational structures" (Air Force, AFPD 38-1, 1996: 1). Additionally, each of the Organizational Entities available to form a structure is defined in detail, so that even organizations with different missions will be composed using Standard Levels of AF organization (Air Force, AFI 38-101, 2006: 10). The result is that all AF organizations are composed of Major Commands (MAJCOMs), of which most are composed of Wings, made up of Squadrons, broken down into Flights. This constitutes a high degree of formalization within the formation of the organizational structure itself.

AF logistics tasks and procedures are highly formalized, as well, governed by AF Instructions, Technical Orders (TOs), and checklists. For example, procedures for issuing and managing spare parts are governed by *Air Force Manual 23-110, USAF Supply Manual*; aircraft refueling operations are regulated by *Air Force Instruction 23-201, Fuels Management*, and applicable TOs; and aircraft maintenance operations fall under *Air Force Instruction 21-101, Aircraft and Equipment Maintenance Management,* which also mandates strict "adherence to and compliance with TOs and supplements" for all aircraft and equipment (Air Force, AFI 21-101, 2006: 18).

This type of procedural standardization is consistent with FAA requirements to ensure the safety of aerospace activities. The establishment of a logistics support organization with this degree of formalization will be of great benefit to the safe operation of the RMLV.

In summary, the AF principles for establishing organizational structure provide a balanced approach to specialization and centralization, and high degree of formalization. Organizational behavior literature and specific examples from the aerospace industry support these approaches as effective within the aerospace context. Therefore, the current AF organizational structure provides a suitable framework for developing the RMLV logistics support organization, which will be addressed in detail in Chapter VI, Analysis of Organizational Structure.

Developing Manpower Requirements

Having established AF policy as the standard for developing organizational structure, AF policy also provides the foundation for establishing the manpower requirements of the RMLV logistics support organization.

The method for determining AF manpower requirements is clearly established within the governance of *Air Force Instruction 38-201, Determining Manpower*

Requirements. The goal of AF manpower requirements determination is to "systematically identif[y] minimum essential manpower required for the most effective and economical accomplishment of approved missions and functions within organizational and resource constraints" (Air Force, AFI 38-201, 2003: 5). In order to accomplish this goal, the AF has established Management Engineering Programs which form the basis for the development of manpower standards and conduct of manpower studies (Air Force, AFI 38-201, 2003: 5). Under this construct, all AF units adhere to a standardized process of determining manpower requirements. The manpower determination process begins with the development of an AF Manpower Standard (AFMS) for the unit of interest, which considers the product or service provided by the unit, the quantity or frequency of the workload, product/service prioritization, any variations to basic requirements, and a detailed breakdown of required grades, skill levels, and officer-enlisted-civilian mix in order to generate a total man-hour requirement (Air Force, AFI 38-201, 2003: 10). AFMS total man-hour requirements are divided by a Man-hour Availability Factor (MAF), reflecting the percentage of work-hours per month an individual is available to perform primary duties, and an Overload Factor, which "ensures effective use of Air Force manpower resources" by assessing different percentages of overload capacity to different duty scenarios, in order to determine the authorized number of manpower positions (Air Force, AFI 38-201, 2003: 13-14).

Certain units may determine Aircraft Maintenance manpower requirements through the use of "aircraft specific maintenance man-hour per flying hour (MMH/FH) factors when more rigorous methods (i.e., conventional manpower standards or Logistics Composite Model manpower determinants) are not available" (Air Force, AFI 38-201, 2003: 16). For instance, in some cases, the small number or impending retirement of certain airframes render rigorous manpower studies non-cost effective and justify the use of MMH/FH data instead.

Additionally, the AFI endorses the use of the Logistics Composite Model (LCOM), a "dynamic computer simulation model that evaluates the interaction between operations and logistics" (Air Force, AFI 38-201, 2003: 18). Guidance for conducting an LCOM study is contained in *Air Force Manual 38-208, Volume 3, Air Force Management Engineering Program (MEP)—Logistics Composite Model (LCOM).* LCOM is designed to provide an assessment of the "best mix [of different support resources] to support a given requirement," and may be applied to a range of weapons systems, from the very large to the very small (Air Force, AFMAN 38-208, 1995: 1). LCOM outputs are based on a specific scenario which includes detailed operational and maintenance data, including: operational environment, primary aircraft assigned, organizational structure with workcenter functional account codes, MAFs, shift data, not-mission-capable supply rates, maintenance policy, failure data, and sortie rates (Air Force, AFMAN 38-208, 1995: 2-3). Maintenance data, specifically, should ideally consist of "at least six months of historical data from the units or locations under study" (Air Force, AFMAN 38-208, 1995: 4). LCOM simulation is an approved manpower-determination method even for "evolving weapons systems" (Air Force, AFI 38-201, 2003: 18); however, the lack of a directly-comparable existing platform within the AF inventory (or the commercial sector) may initially impose significant challenges to establishing a successful LCOM simulation for the RMLV. Still, the process through which the LCOM simulation assigns aircraft support resources to operational requirements will be relevant to accomplishing a similar function within MILEPOST, until such time as sufficient data is amassed for an LCOM simulation. This functionality is addressed in greater detail in Chapter VIII, Conclusions and Future Research.

In summary, while the preferred method to exactly establish RMLV manpower requirements begins with an LCOM simulation study, there is a challenging lack of data availability, particularly in the realm of historical maintenance data. A secondary method involves applying existing AFMS documents, but this method will face additional challenges in adapting those AFMS assumptions to the specific nature of RMLV support requirements. Utilizing MMH/FH factors would likely be acceptable due to small fleet size; however, again, there is a lack of platform-specific data to establish these factors. Therefore, in Chapter VII, Manpower Assessment, data from all available areas will be investigated to derive the most realistic manpower requirements assessment from a combination of AF methods.

Life Cycle Costing

Finally, Department of Defense policy will also be applied to determine how to address the Life Cycle Cost implications of logistics support to the RMLV fleet.

RMLV development will be considered a “major defense acquisition program” and, as such, falls under the review responsibility of the Cost Analysis Improvement Group (CAIG). The CAIG receives a “comprehensive assessment of program Lifecycle cost” at each major milestone decision point from the Office of the Secretary of Defense (OSD) CAIG (Defense Acquisition Guidebook, 2006: 3.4-3.4.1). The OSD CAIG assessment contains both the program office’s estimate of total life cycle cost and the cost analysis of each relevant DoD component (Defense Acquisition Guidebook, 2006: 3.4.1).

Program costs are divided into seven standardized categories: Development Cost, Flyaway Cost, Weapon System Cost, Procurement Cost, Program Acquisition Cost, Operating and Support (O&S) Cost, and Life Cycle Cost. Each of these cost terms is defined in relation to the elements of the Work Breakdown Structure (WBS), the source of budget appropriations, and the life-cycle cost categories included (Department of Defense, DoD 5000.4-M, 1992: 44). The life-cycle cost categories define whether the cost term is contractor or in-house, recurring or nonrecurring, and whether it is relevant to the Research and Development (R&D), Investment, or O&S phases of the program life cycle, as depicted in Table 2:

Table 2. Life Cycle Costs (Department of Defense, DoD 5000.4-M, 1992: 50)

	COST CATEGORIES					APPROPRIATIONS					WORK BREAKDOWN STRUCTURE			
TERM	RESEARCH & DEVELOPMENT		INVESTMENT		OPERATING & SUPPORT	RDT&E	PROC. 3/	MILCON	O&M	OTHER 4/	PRIME MISSION EQUIPMENT SYSTEM ENG/ PROGRAM MGT SYSTEM TEST & EVALUATION	TRAINING PECULIAR SUPPORT EQUIPMENT DATA OPER./SITE ACTIVATION	INITIAL SPARES AND REPAIR PARTS	INDUSTRIAL FACILITIES
	NON-RECURRING	RECURRING	NON-RECURRING	RECURRING										
DEVELOPMENT COST	$	$				$					$	$		5/
FLYAWAY COST 1/	$	$	$	$		$	$				$			
WEAPON SYSTEM COST			$	$			$				$	$ 6/		7/
PROCUREMENT COST			$	$			$				$	$	$	7/
PROGRAM ACQUISITION COST 2/	$	$	$	$		$	$	$			$	$	$	
OPERATING & SUPPORT COST					$		$	$	$	$	8/	8/	8/	8/
NOTE: THE SUM OF PROGRAM ACQUISITION, OPERATING AND SUPPORT, AND OTHER COSTS (E.G., MILITARY AND CIVILIAN MANAGEMENT PAY) EQUALS LIFE CYCLE COST														
LIFE CYCLE COST	$	$	$	$	$	$	$	$	$	$	$	$	$	$

NOTES
1 GENERIC TERM DEPENDING UPON COMMODITY. CAN ALSO BE CALLED "ROLLAWAY" OR "SAILAWAY"
2 ALSO KNOWN AS "ACQUISITION COST" OR "PROGRAM COST"
3 INCLUDES SHIPBUILDING AND CONVERSION, NAVY APPROPRIATION
4 OTHER APPROPRIATIONS (e.g. MILITARY PERSONNEL) AND FUNDS ARE INCLUDED AS APPROPRIATE
5 WHEN INDUSTRIAL FACILITIES ARE FUNDED BY RDT&E IT WILL BE INCLUDED AS APPROPRIATE
6 GENERALLY, OTHER PROGRAM PECULIAR WBS ELEMENTS (I.E., FLIGHT SUPPORT OPERATIONS AND SERVICES FOR SPACECRAFT) APPLY WHEN PROCUREMENT SUPPORTED
7 EXCLUDES INDUSTRIAL FACILITIES WHEN FUNDED AS A SEPARATE BUDGET LINE ITEM
8 THE MIL STD 881 WORK BREAKDOWN STRUCTURE DOES NOT APPLY

Life Cycle Cost, shown across the bottom row, includes “ALL WBS elements; ALL affected appropriations; and encompasses the costs, both contractor and in house effort, as well as existing assets to be used, for all cost categories” (Department of Defense, DoD 5000.4-M, 1992: 49). As such, it is the total program cost to the government over the entire life cycle of the system, from research to disposal. The Life Cycle Cost of a program under consideration is assessed early in the life of the project, and continuously reassessed throughout.

The cost assessment process is highly structured. First, the acquisition program office is responsible for preparing a Cost Analysis Requirements Description (CARD) describing the “salient features of the program and of the system being acquired…as a basis for cost-estimating” (Department of Defense, DoD 5000.4-M, 1992: 8). The CARD follows a standardized outline addressing 12 aspects of the program: System Overview, Risk, System Operational Concept, Quantity Requirements, System Manpower Requirements, System Activity Rates, System Milestone Schedule, Acquisition Plan and/or Strategy, System Development Plan, Element Facilities Requirements, Track to Prior CARD, and Contractor Cost Data Reporting Plan (Department of Defense, DoD 5000.4-M, 1992: 10-20). Within these 12 aspects, several sub-categories are of interest from the logistics support perspective: Reliability; Maintainability, including maintenance man-hours per operating hour and personnel requirements and associated skill levels at the maintenance unit level; Portability and Transportability and their effect on logistics support requirements; Organizational Structure including a UMD, notional, if necessary; Logistics Support Concept, including organic versus contractor, scheduled maintenance and overhaul points, maintenance levels and repair responsibilities, and repair versus replacement criteria; Supply; Training for operators, maintainers, and support personnel; and System Manpower Requirements (Department of Defense, DoD 5000.4-M: 14-18).

Second, cost estimates are developed by the program office and DoD component, as applicable, in accordance with standardized estimation practices. Cost estimates are required to capture "all sunk costs and a projection for all categories of the life-cycle costs for the total planned program" to include: R&D, Investment, and O&S (Department of Defense, DoD 5000.4-M, 1992: 29-30). Statistical Estimates, Engineering and Analogy Estimates, and Actual Costs will be utilized as practical for the program milestone. For example, Actual Costs will not be available in the early phases of the program, during which estimates will rely more heavily on statistical techniques (Department of Defense, DoD 5000.4-M, 31-32). Comparison of multiple methods is encouraged, and the estimate should identify and quantify uncertainty, address contingencies, and include sensitivity analysis (Department of Defense, DoD 5000.4-M, 33).

The CARD, program office estimate, and DoD component cost analysis for each alternative under consideration are presented for review and revision to the OSD CAIG upon the approach of major milestone decisions (Department of Defense, DoD 5000.4-M, 1992: 28-29). The presentation format is also highly structured, including the following elements: Overview, Alternative Descriptions, Program Manager Presentation, Presentation of the DoD Component Cost Analysis, Present Value of Alternatives, Preferred Alternative, Time-Phased Program Estimates, Estimate Detail, Relation to FYDP, Cost Estimating Relationship Presentation, Contractor Cost Data Reporting

Status, Cost Track, Unit Cost Comparisons, Design-to-Cost, Personnel Requirements, and O&S Comparisons of alternatives to include fuel, crew size, maintenance man-hours per operating hour, manpower requirements by skill-level, and annual O&S costs for the required force structure unit (Department of Defense, DoD 5000.4-M, 1992: 34-36). These last two presentation elements reinforce the importance of logistics support manpower requirements throughout the course of program development.

The OSD CAIG then presents the CARD, the estimates, and supporting documentation to the CAIG, who will provide a final report on the program to the Defense Acquisition Board.

While a comprehensive cost estimate in accordance with DoD policy is outside the scope of this thesis, certain elements of the Life Cycle Cost estimate will be addressed in response to the fourth research question. Chapter VIII, Conclusions and Future Research, will include an assessment of the costs of logistics support Personnel Requirements and Training to the maximum degree possible.

Summary

In summary, a thorough literature review has established the importance of defining logistics manpower support requirements early in the development of the RMLV. Logistics manpower support will be assessed based on the regeneration activities identified in MILEPOST, and will be supported from within the Maintenance, Logistics Readiness, Civil Engineer, and Security Forces functions under the existing AFSC structure. The RMLV organizational structure will be determined in accordance with AF organizational development policy. Manpower requirements will, likewise, be assessed in accordance with AF policy. Finally, Life Cycle Cost implications will be addressed in accordance with DoD guidance. Chapter IV, Methodology, will specifically address the research methods that will be utilized within each of these research areas. First, however, a more thorough introduction to the MILEPOST model that forms the foundation for this research will be provided in the following chapter.

III. Introduction to MILEPOST

The MILEPOST model is composed of three independently-developed, sequential processes that are linked within the Arena construct to provide a timeline of all the activities that occur from RMLV landing until the pre-launch sequence for its subsequent mission. In this section, we will review each segment of the regeneration process. This process, along with the activities identified therein, forms the foundation for assigning workforce requirements in support of the RMLV.

Part 1: Post-Landing Operations

The activities identified in this portion of the model were developed based on a comparison of Space Shuttle Orbiter and F-16 post-landing recovery operations. The results of the comparison showed that the Orbiter required four processes that are not performed on the F-16. Of the remaining processes, some of the simpler activities were held in common; however, a greater number of activities shared a common purpose, but involved much greater complexity and longer completion times for the Shuttle (Martindale, 2006: 17). This implies that the AF will experience a few shortfalls in expertise for RMLV ground support; will have sufficient expertise for some activities; and will have sufficient technical background, but require additional training, for a greater number of support activities. Following is a by-segment assessment of the Post-Landing Operations portion of the MILEPOST model.

Segment 1, Landing, Taxi, and Initial Safing, is shown in Figure 4. This process segment addresses the RMLV landing, travel to the recovery apron, and various initial safing procedures for the ground support crew. It incorporates elements of both aircraft and Shuttle Recovery operations. A vehicle that can taxi to the recovery apron is aircraft-like, and APU shutdown procedures are common to all airframes. However, the Ground Support Equipment (GSE) positioned for the vehicle, the drag chute pyrotechnic safing, and the LOX safing operations are derived from Shuttle recovery procedures (Martindale, 2006: 32).

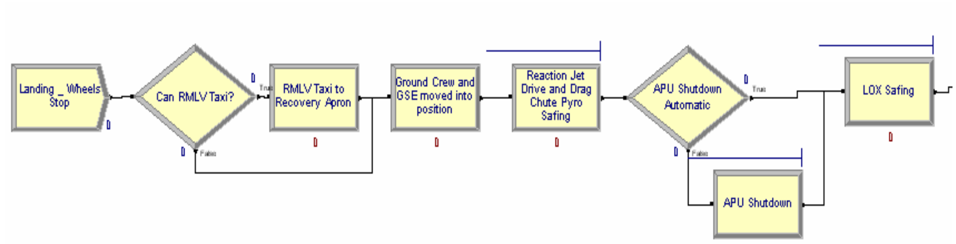

Figure 4. Landing, Taxi, and Initial Safing (Martindale, 2006: 32)

Segment 2, Safety Assessment and Final Safety Call, is depicted in Figure 5. This segment deals with ensuring that the RMLV is safe for the ground crews to perform recovery operations and transport the vehicle to the maintenance facility. The specialties required for this segment of the process depend upon whether the RMLV design is fueled by hypergolics and whether an RMLV that does require hypergolic fuel includes internal gas detection equipment. If there are no hypergolic fuels involved, or once the vehicle passes its safety inspection, the rest of the recovery operation can proceed (Martindale, 2006: 32).

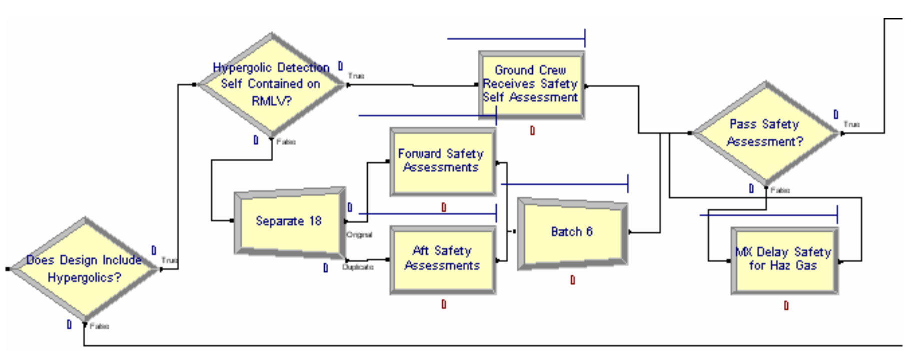

Figure 5. Safety Assessment and Final Safety Call (Martindale, 2006: 32)

Segment 3, RMLV Preparation for Transportation, is shown in Figure 6. This segment begins the actions required to prepare the RMLV for transportation to a maintenance facility. It includes several processes that occur in parallel, including the hazardous gas purge, external coolant requirement, and TPS inspection required in Shuttle operations. Installing lock pins and protective covers for vents are common actions for a variety of aircraft (Martindale, 2006: 34).

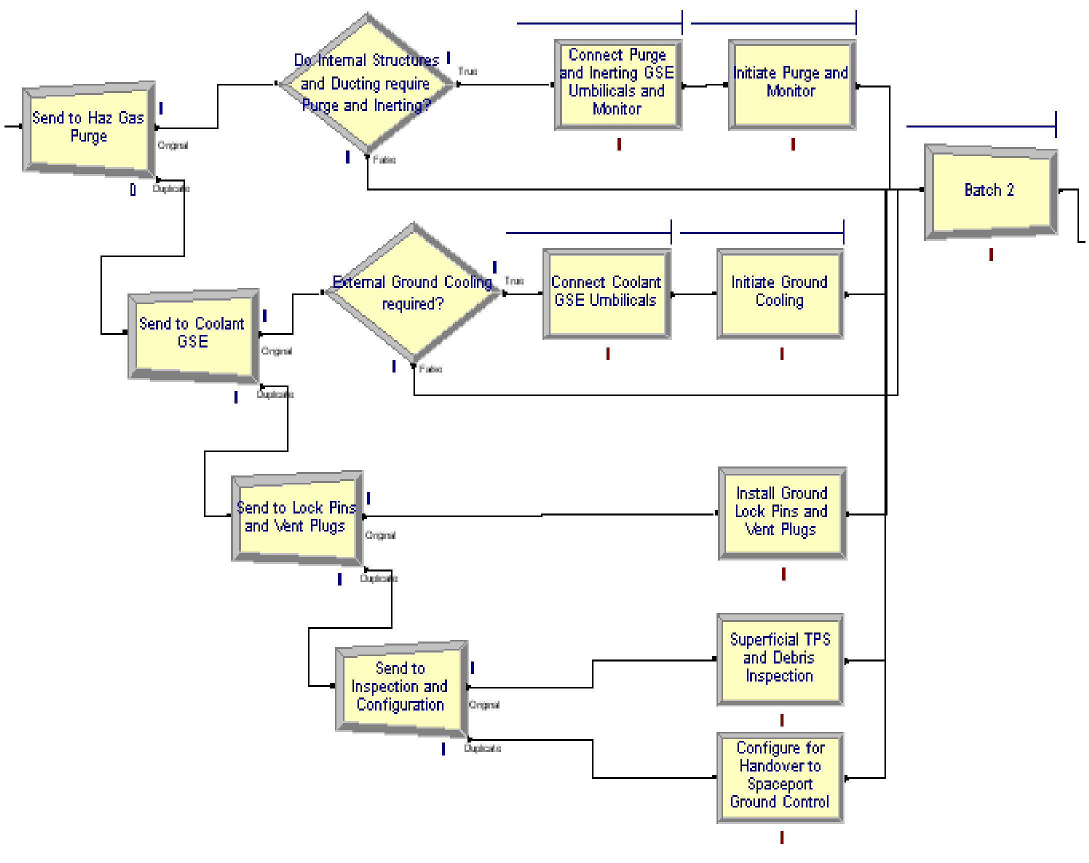

Figure 6. RMLV Preparation for Transportation (Martindale, 2006: 34)

Segment 4, Handling External Stores, is depicted in Figure 7. The model accounts for the possibility that the RMLV may be designed with the capability to land with external stores attached. This portion of the model is best represented by fighter or bomber aircraft that land with unexpended ordnance (Martindale, 2006: 35).

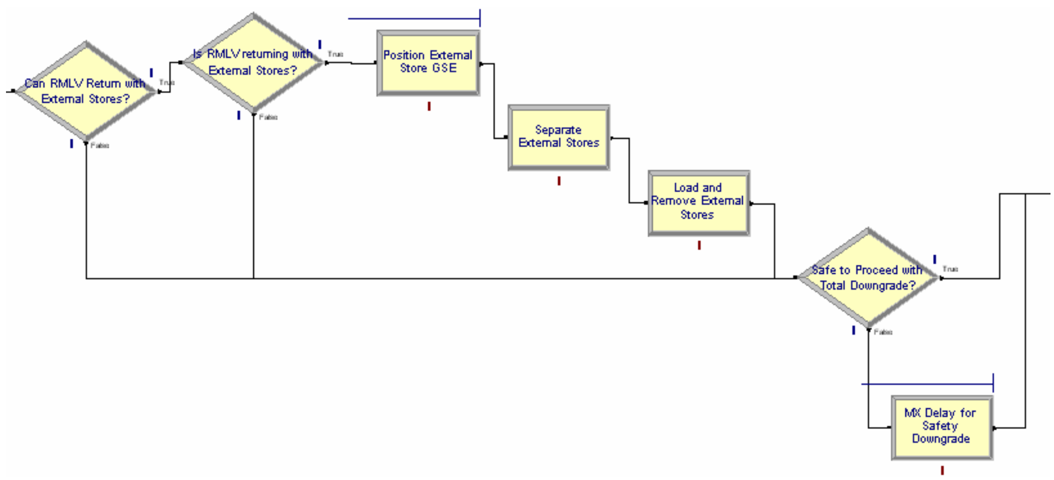

Figure 7. Handling External Stores (Martindale, 2006: 35)

Segment 5, Safing Sequence, which is shown in Figure 8, addresses the final safing procedures prior to towing operations. While the Orbital Maneuvering System/ Reaction Control System (OMS/RCS), Main Engine (ME) Tank Venting, and hypergolic fuel process requirements are unique to spacecraft, propulsion system configuration and Inertial Navigation System (INS) safing are common practices to aircraft (Martindale, 2006: 36).

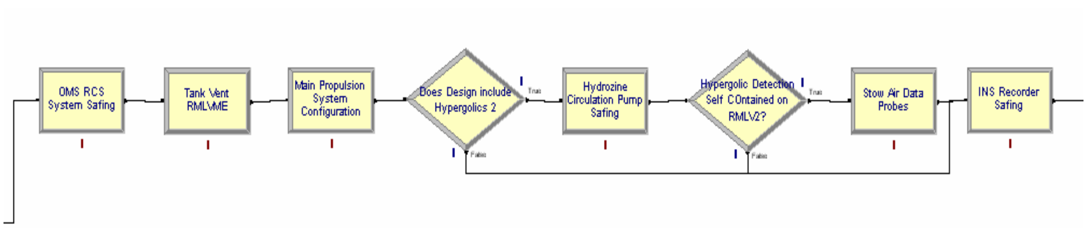

Figure 8. Safing Sequence (Martindale, 2006: 36)

Segment 6, depicting Part 2 of RMLV Preparation for Transportation operations, is shown in Figure 9. The second stage of preparation occurs at the same time as the safing sequence described above. In this process the recovery team installs protective covers on equipment as necessary, positions the tow vehicle, and monitors on-board systems. These actions were modeled on Shuttle recovery operations, but the basic processes are consistent with operations performed by aircraft maintenance personnel (Martindale, 2006: 37).

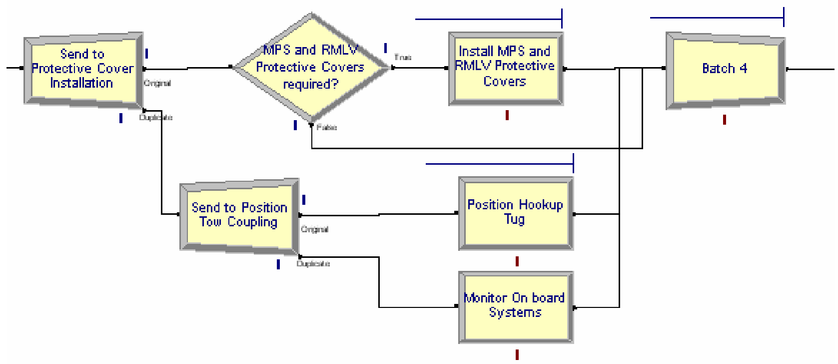

Figure 9. RMLV Preparation for Transportation, Part 2 (Martindale, 2006: 37)

Segment 7, Tow Preparations and Towing to the Maintenance Facility, is shown in Figure 10. Final tow preparations also occur in parallel with the safing sequence, and include standard airframe actions like connecting the tow vehicle, checking connections, and removing chocks (Martindale, 2006: 37). Towing is the final action within Post-Landing Operations, after which the entity in the model is transitioned into Ground Maintenance Operations (Martindale, 2006: 38).

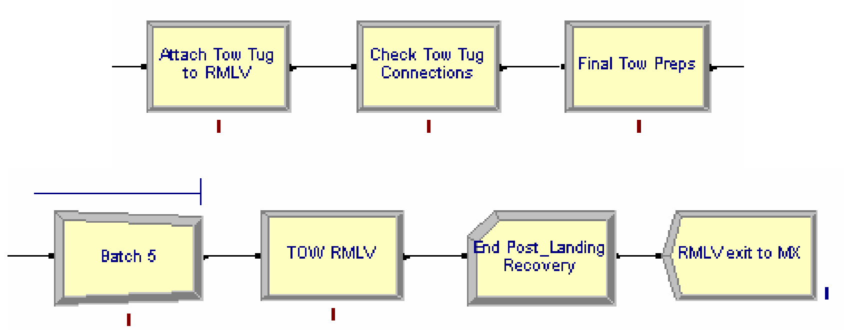

Figure 10. Tow Preparations and Towing to Maintenance Facility (Martindale, 2006: 38)

Because the RMLV launch and reentry patterns are most similar to those of the Space Shuttle Orbiter, it was the primary source of activities in the Post-Landing Operations phase. As we have seen in each segment, however, many of the activities contained within the processes are similar to activities performed after an aircraft landing. These similarities will be examined in greater detail in Chapter V, Analysis of Technical Expertise.

Part 2: Ground Maintenance Operations Cycle

The Ground Maintenance Operations Cycle is the portion of the model that most closely relates to aircraft support operations, simply because the design of a spacecraft includes the same major components as the design of an aircraft: fuel systems, hydraulic systems, propulsion systems, electrical and environmental systems, and structural systems. Maintenance of unique systems like the Thermal Protection System (TPS) may be compared to maintaining the specialized surface material applied to the B-2. Bomber aircraft exhibit more similarities to Shuttle maintenance than fighter aircraft, as the larger size and greater complexity of the platform require a higher degree of maintenance interaction between missions (Pope, 2006: 15). In general, the B-2 provides a strong source for model development due to its mission, maintenance footprint, and specialized structural material (Pope, 2006: 17). Key differences identified between Shuttle and B-2 maintenance operations include the even larger size and greater complexity of the Shuttle; performance of Shuttle refueling operations immediately prior to launch rather than as part of ground maintenance operations; and more frequent landing gear and tire replacement maintenance actions due to the Shuttle's higher landing speeds and fewer, lighter tires (Pope, 2006: 15).

Segment 1, Transportation to Maintenance Bay, is depicted by Figure 11. In this portion of the model, the vehicle is transitioned via the towing operation established in Post-Landing Operations. For the maintenance activities to follow, this segment allows the user to define the number of engines on the RMLV. The remaining operations result in the RMLV being positioned in the maintenance bay, ready for assessment and repair actions (Pope, 2006: 26).

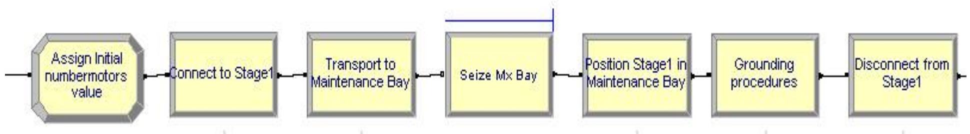

Figure 11. Transportation to Maintenance Bay (Pope, 2006: 26)

Segment 2, Initial Maintenance Assessment, is shown in Figure 12 below. The first step in RMLV maintenance is to download information from the Integrated Vehicle Health Monitoring (IVHM) system. If IVHM is not part of the RMLV design, maintenance personnel will have to perform system health assessments through other means. Afterwards, maintenance stands are positioned and electrical connections are established to provide power as required to various on-board systems. After performance of these actions, the model allows for a series of maintenance actions performed in parallel, beginning with battery testing (Pope, 2006: 27).

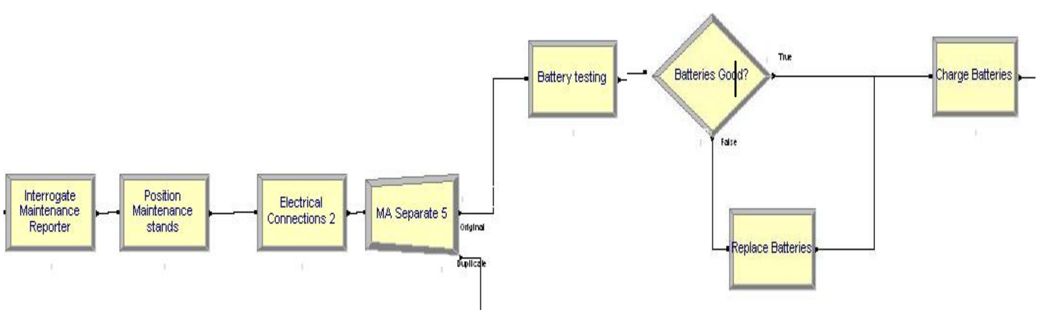

Figure 12. Initial Maintenance Assessment (Pope, 2006: 27)

Segment 3, Avionics, Flight Controls, and Sensors, is modeled in Figure 13. This segment occurs in parallel with battery testing. Maintenance personnel test the avionics equipment to ensure that it is communicating properly and properly controlling the flight surfaces. At the same time, the lower module "allows for the removal of experimental data or telemetry information" collected by on-board sensors (Pope, 2006: 28).

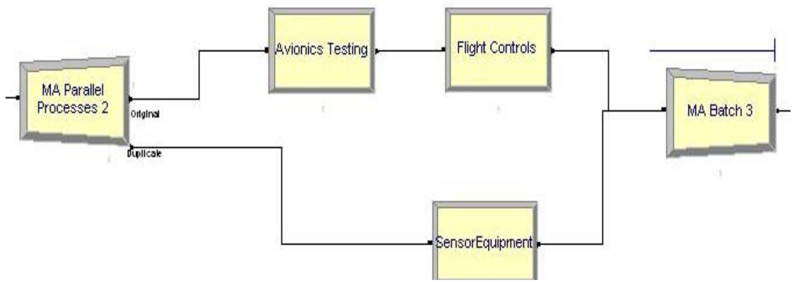

Figure 13. Avionics, Flight Controls, and Sensors (Pope, 2006: 28)

Segment 4, shown in Figure 14, addresses Second Stage Connection Testing. After completion of Segments 2 and 3, maintenance personnel test the RMLV electrical connections for the second stage, after which the vehicle enters a series of parallel processes (Pope, 2006: 29).

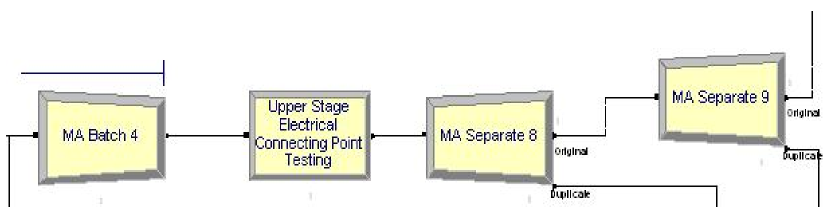

Figure 14. Second Stage Connection Testing (Pope, 2006: 29)

Segment 5 initiates a set of Parallel Processes, shown in Figure 15. This segment involves drag chute replacement, TPS inspection and repair actions, Stage 2 mechanical and hardware component assessment, and removal/replacement (R2) of the buffer plug which “offers a secure connection that allows for separation between two vehicles in motion” (Pope, 2006: 29).

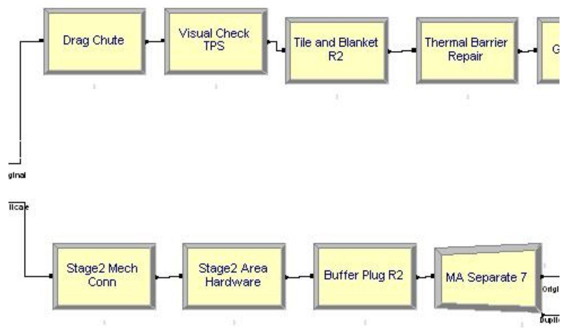

Figure 15. Parallel Processes (Pope, 2006: 29)

Segment 6 is a continuation of those Parallel Processes, as shown in Figure 16. To complete the processes initiated above, RMLV mechanics will continue TPS repair activities while fluid systems are being assessed and repaired as necessary. Because maintenance repair access requires the removal of TPS tiles, the RMLV undergoes a full systems check prior to TPS waterproofing. On the bottom branch, the RMLV enters the engine repair process. As each engine is assessed and/or repaired, the Number of Motors module will be increased; the RMLV will exit the cycle when the count is equal to the total number of engines assigned prior to the start of Ground Maintenance Operations (Pope, 2006: 31).

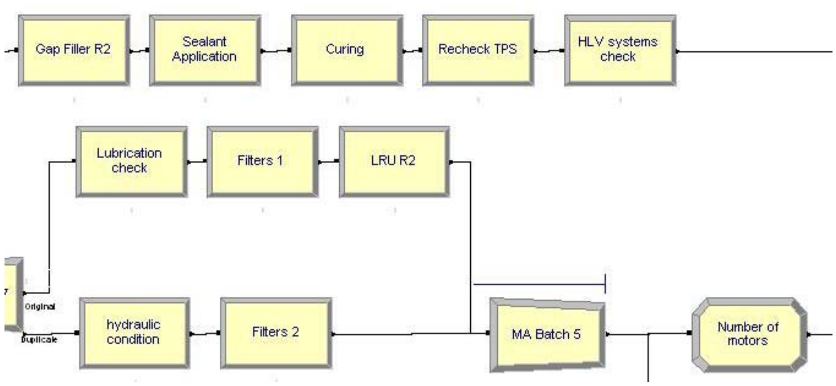

Figure 16. Parallel Processes, Continued (Pope, 2006: 29)

Segment 7, Engine Maintenance, is depicted in Figure 17. "One aspect of the launch vehicle that will differ from aircraft maintenance is the fact that the engine will require certain tasks to be performed after every flight" (Pope, 2006: 31). However, these maintenance repair actions are performed in parallel with TPS, avionics, and fluids actions, reducing the overall maintenance time. A design including modular motors that can simply be removed and replaced would further reduce overall maintenance time.

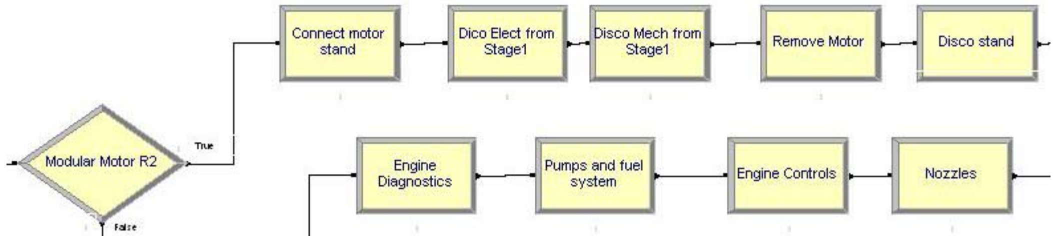

Figure 17. Engine Maintenance (Pope, 2006: 31)

Engine Maintenance operations are continued in Segment 8, shown in Figure 18. This section of the model completes engine diagnostics and repair. Segments 7 and 8 are repeated for each engine (Pope, 2006: 33).

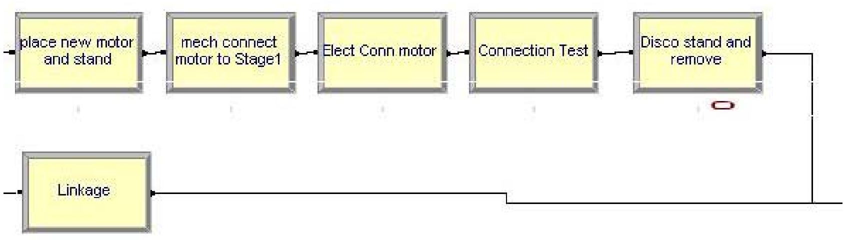

Figure 18. Engine Maintenance, Continued (Pope, 2006: 33)

Segment 9, modeling Maintenance Completion, is shown in Figure 19. The final segment of the Ground Maintenance Operations Cycle brings together all of the parallel processes that have been performed in the maintenance bay. It culminates in the completion of TPS waterproofing and engine maintenance while preplanned maintenance, Time Compliance Technical Order (TCTO) actions, and landing gear and tire maintenance are completed in parallel. The final action is an engine check which, if good, routes the RMLV to Pre-launch Operations (Pope, 2006: 34).

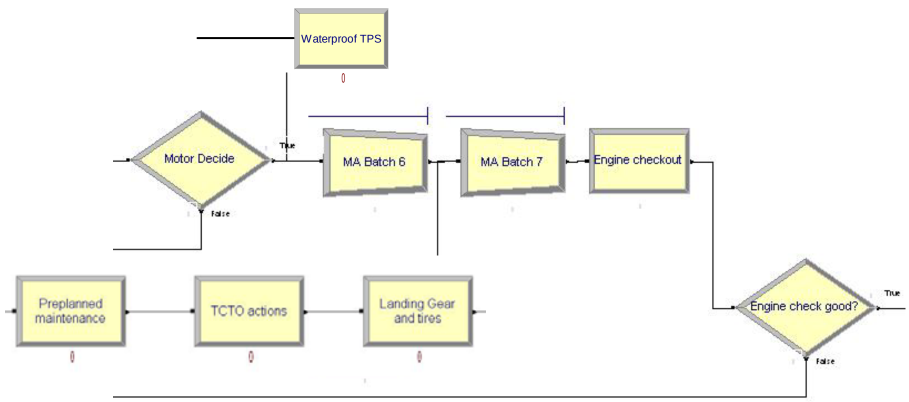

Figure 19. Maintenance Completion (Pope, 2006: 34)

RMLV ground maintenance operations exhibit many similarities to aircraft maintenance operations. The primary differences between the two processes are the complexity and completion time of certain activities and the requirement for more extensive maintenance between each flight in areas such as the engines and landing gear. This implies that while an RMLV maintenance workforce may be larger than an aircraft maintenance workforce, it will not differ significantly in its composition of technical expertise.

Part 3: Pre-launch Operations

RMLV pre-launch operations contain the highest degree of variability within the model. Because the RMLV design concept is not yet solidified, Stiegelmeier had to account for many potential pre-launch scenarios based on a variety of existing platforms. These scenarios include horizontal or vertical integration of the three stages, pre-integration of the first and second stages, pre-integration of the second stage and payload, and integration occurring on or off of the launch pad. Models for each of these scenarios were drawn from the Shuttle, aircraft, Atlas V, Delta IV, Zenit 3SL, and ICBM operations (Stiegelmeier, 2006: 26). This set of processes differs most significantly from standard aircraft operations, but still incorporates skill sets that are available in today's AF manpower structure.

Segment 1, Pre-integration of Second Stage and Payload, is shown in Figure 20. The first determination, which occurs simultaneously with ground maintenance operations, is whether pre-integration of the second stage and payload will occur (Stiegelmeier, 2006: 63). These operations require support personnel using specialized GSE to secure the payload, align it with the second stage, and make all mechanical and electrical connections. Although the pre-integration concept is modeled on the Shuttle pre-integration of boosters and external tanks (Stiegelmeier, 2006: 70), this process is similar to loading external munitions on aircraft.

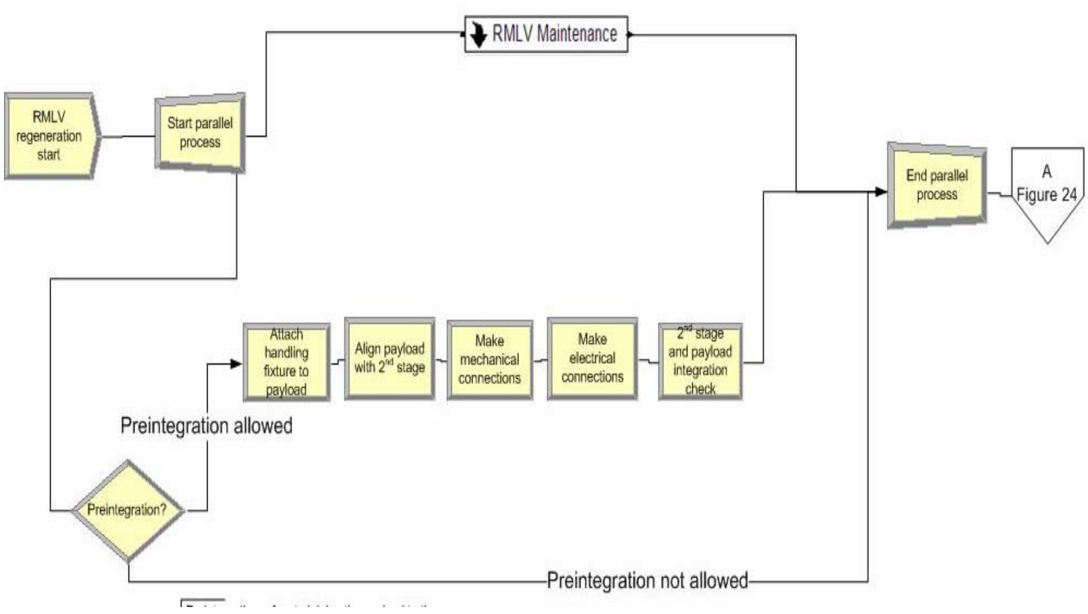

Figure 20. Pre-integration of Second Stage and Payload (Stiegelmeier, 2006: 70)

Segment 2, Vehicle Integration Preliminary Considerations, is shown in Figure 21. This segment depicts three possible vehicle integration scenarios: integration on the launch pad, integration in the maintenance or storage facility, or integration in a separate facility (Stiegelmeier, 2006: 64). On-pad integration is modeled on Expendable Launch Vehicle operations, while off-pad integration scenarios are based on the Atlas V and Delta IV Evolved Expendable Launch Vehicles (Stiegelmeier, 2006: 70). This segment is primarily composed of decision modules and will only require manpower if the vehicle must be transported to the launch pad or integration facility.

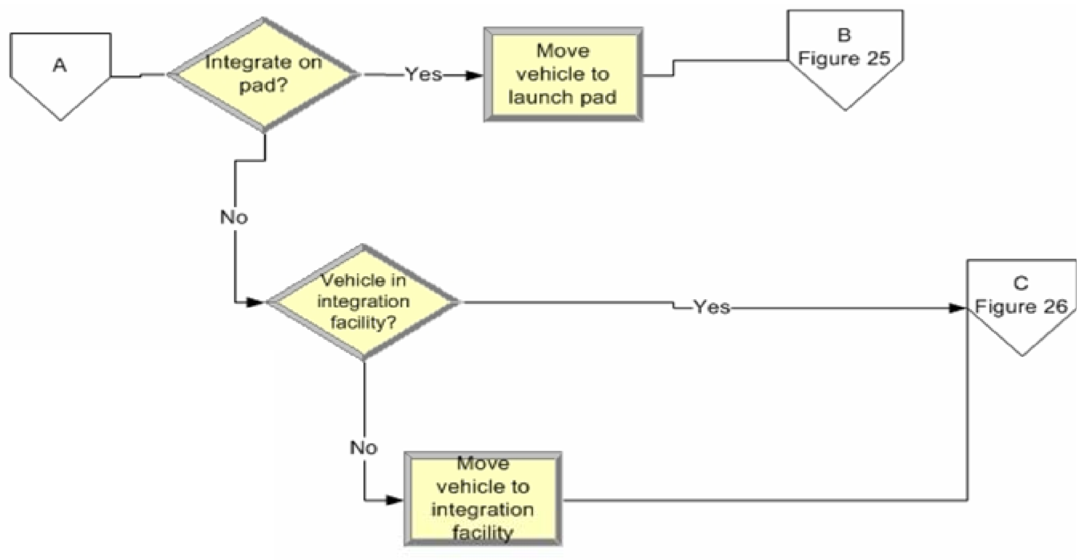

Figure 21. Vehicle Integration Preliminary Considerations (Stiegelmeier, 2006: 70)

Segment 3, shown in Figure 22, addresses operations required for Vehicle Integration, Integrate on Pad. The upper branch represents a payload previously integrated to the second stage, while the lower branch depicts a sequential integration of all three stages (Stiegelmeier, 2006: 65). As in Segment 1, the positioning, alignment, and connection of each of stage are similar to (though more complex than) loading aircraft ordnance.

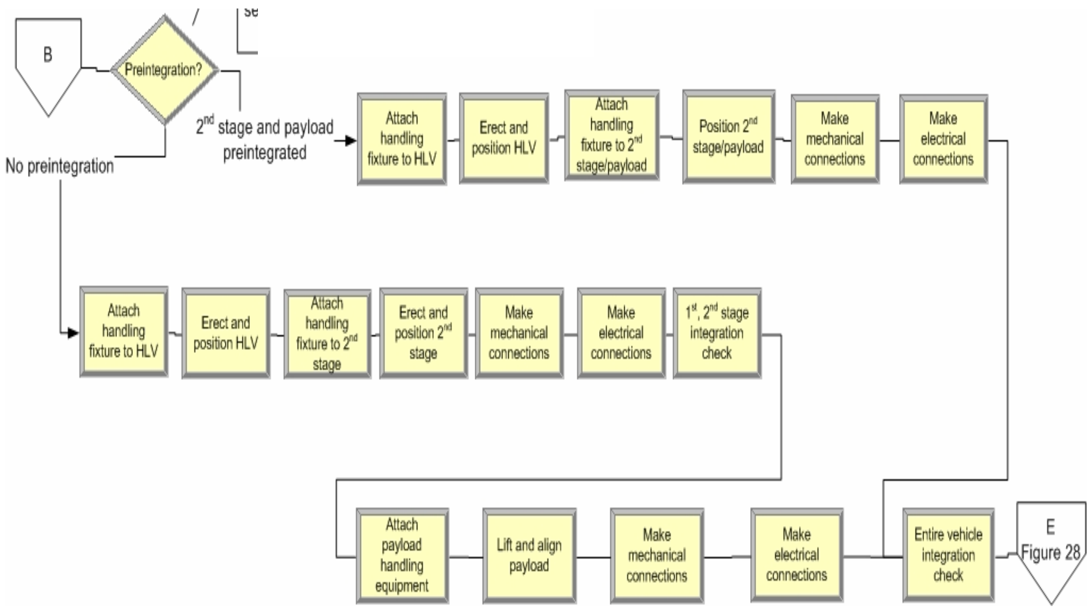

Figure 22. Vehicle Integration, Integrate on Pad (Stiegelmeier, 2006: 65)

Segment 4, addressing the modeled option for Vehicle Integration, Integrate off Pad, is shown in Figure 23. This portion of the model, in which vehicle integration occurs at a facility away from the launch pad, includes a long series of processes depending upon how many and what type of integration actions are required (Stiegelmeier, 2006: 66). It accounts for pre-integration, vertical or horizontal, on the upper branch, or sequential integration, vertical or horizontal, on the second branch. Atlas V provided the model for vertical integration activities, while Delta IV and Zenit 3SL were referenced for horizontal integration (Stiegelmeier, 2006: 71). After each stage integration action, electrical and mechanical connection checks are required, culminating with an entire vehicle check. Once stages are mated, this portion of the model depicts the capability to load the payload, hypergolic fuel, and/or ordnance in the integration facility or on the launch pad (Stiegelmeier, 2006: 66). The activities within the integration process, regardless of the design alternatives, will require personnel with loading expertise as discussed in Segments 1 and 3 as well as fueling expertise.

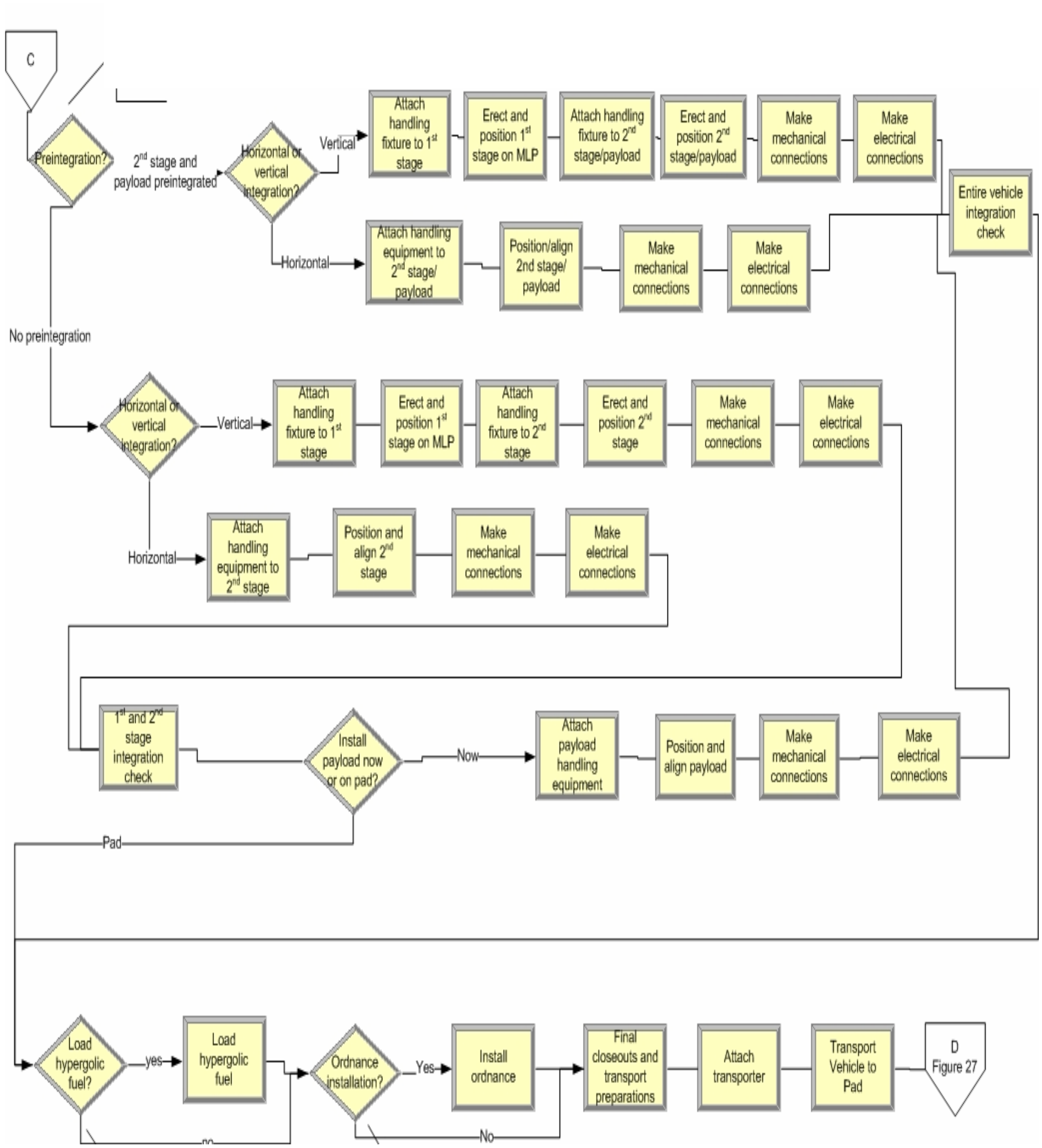

Figure 23. Vehicle Integration, Integrate off Pad (Stiegelmeier, 2006: 66)

Segment 5 depicts Launch Pad Operations for Vehicle not Integrated on Pad, and is shown in Figure 24. The upper branch is based on the Zenit program and represents an RMLV that is transported to the launch pad horizontally on GSE that includes the vehicle erector mechanism (Stiegelmeier, 2006: 71). The lower branch depicts a vehicle that is transported to the pad in a vertical orientation, like the Shuttle, and accounts for the possibility of payload integration on the launch pad (Stiegelmeier, 2006: 67). The primary activities during this process are the operation GSE and integration of the payload, if necessary.

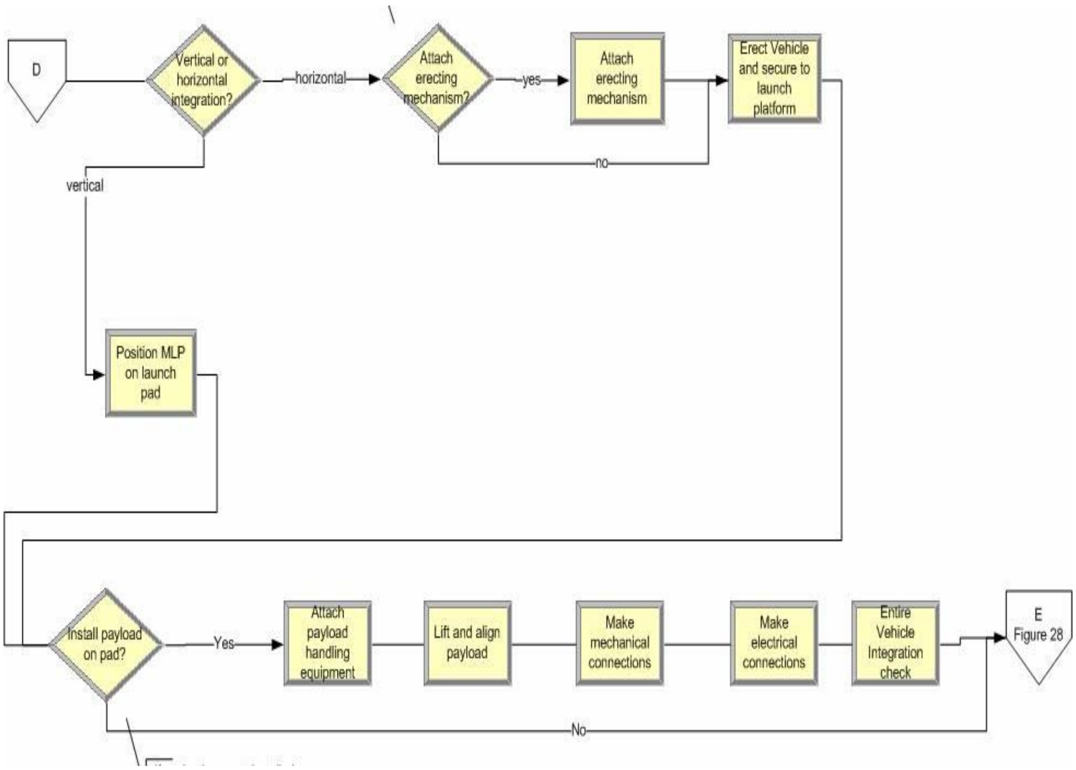

Figure 24. Launch Pad Operations for Vehicle not Integrated on Pad (Stiegelmeier, 2006: 67)

Segment 6, Launch Pad Operations, is depicted in Figure 25. In this segment, ground support personnel make umbilical connections to the RMLV as required, based on the design configurations of the Shuttle, Atlas V, and Zenit programs, respectively (Stiegelmeier, 2006: 71). The model then allows alternative paths based on the use of hypergolic fuels and RP-1 in each of the first and second stages, as well as the ability to conduct parallel fueling operations (Stiegelmeier, 2006: 68). Cryogenic fueling operations are represented in the next, and final, segment.

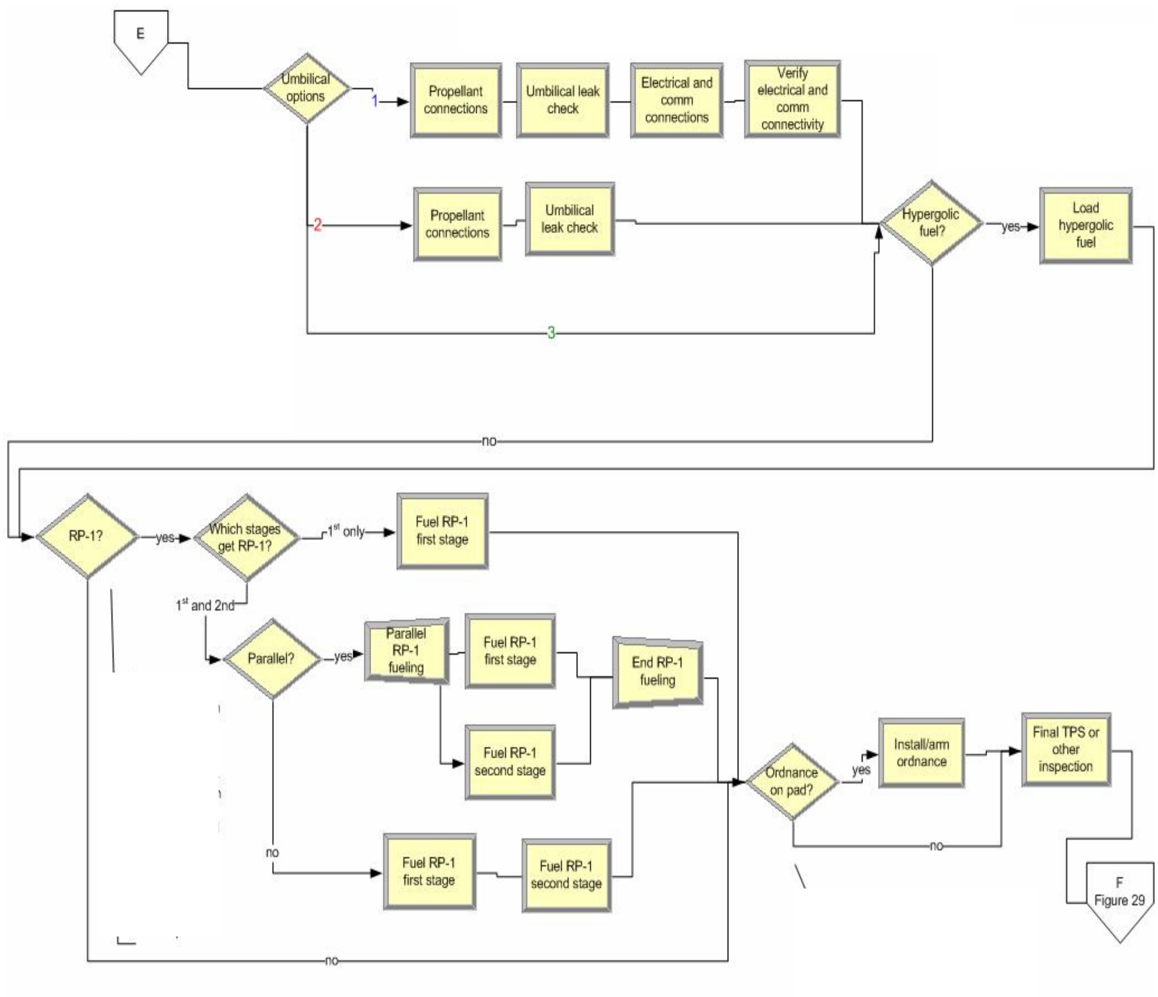

Figure 25. Launch Pad Operations (Stiegelmeier, 2006: 68)

Finally, Segment 7, Propellant Loading, is depicted in Figure 26. This segment is the final operation prior to launch and depicts the loading of cryogenic fuels, if required, via three alternatives: stages loaded in parallel, oxidizer and fuel loaded in parallel (Box 1); stages loaded in parallel, oxidizer and fuel loaded sequentially (Box 2); or stages loaded sequentially with fuel and oxidizer loaded sequentially (Box 3) (Stiegelmeier, 2006: 69). The fueling activities depicted in Segments 7 and 8 have some degree of similarity to aircraft fueling operations; however, this model depicts a much more complicated array of fueling possibilities, and the design alternatives will dictate the amount of additional training needed in the aircraft fuel workforce.

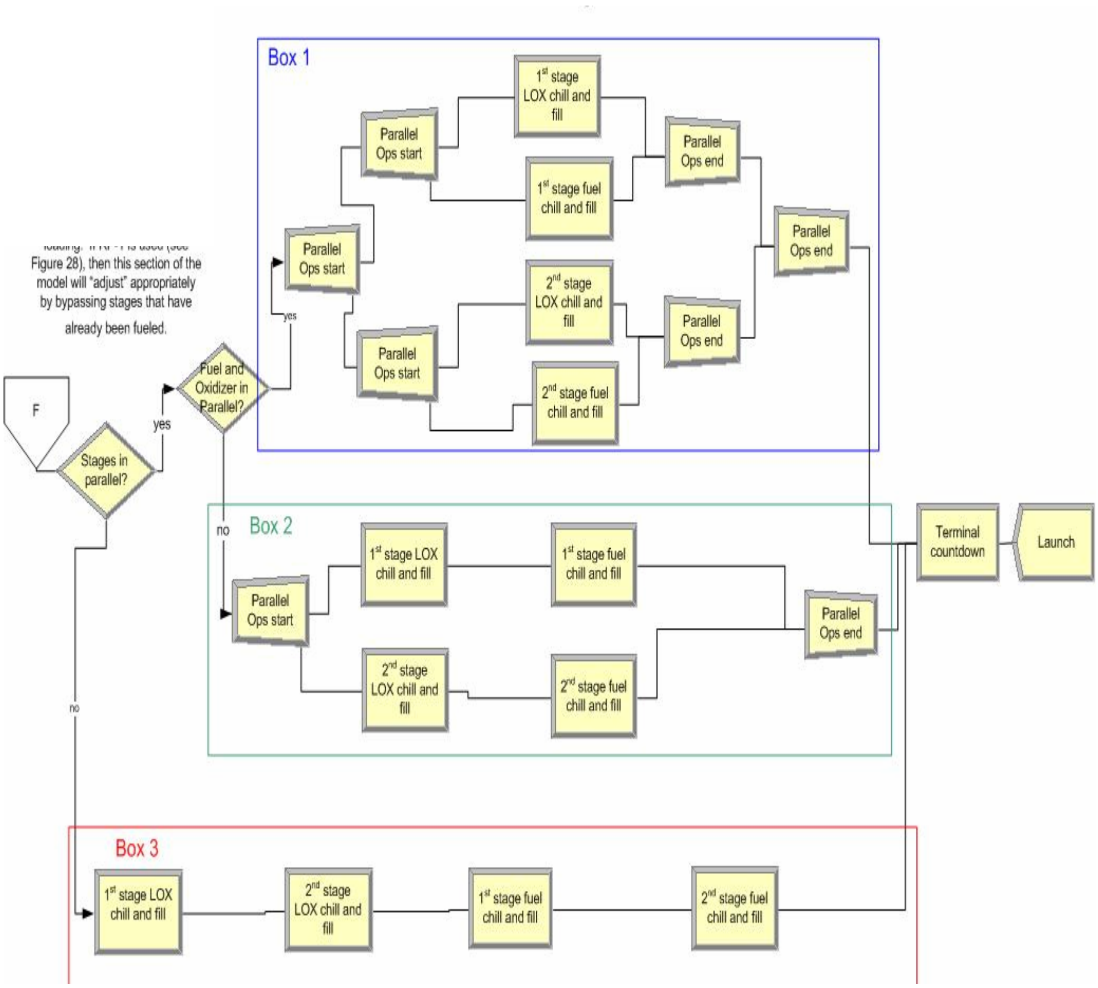

Figure 26. Propellant Loading (Stiegelmeier, 2006: 69)

Summary

The MILEPOST model diagrams the series of activities required to recover, maintain, and prepare an RMLV for launch. As such, it provides the foundation for ground support requirements that must be upheld by the RMLV logistics workforce. In this segment-by-segment review of the model, we have identified the ways in which RMLV operations differ from aircraft operations in order to gain preliminary understanding of the AF manpower structure's ability to support this vehicle. Chapter VI, Analysis of Organizational Structure, will further assess the type of AF organization that would best support the mission sequence defined by the model, while Chapter V, Analysis of Required Technical Expertise, will examine in greater detail the relationship between current AFSCs and the activities defined by the model.

IV. Methodology

This research effort was primarily a qualitative study, an effort to "answer questions about the complex nature" of providing logistics support to a newly-emerging space launch platform (Leedy, 2005: 94). As such, the research process exhibited the following characteristics:

Purpose: The purpose of the research effort was to gain a greater understanding of the logistics ground support implications of the RMLV. Research was exploratory in nature, and research and observations throughout the research period were used to develop a workforce projection by synthesizing information from comparable sources.

Process: Throughout the research process, research focus and research and analysis methods evolved as a more complete understanding of RMLV support requirements and logistics implications was developed.

Data Collection: Logistics support requirements can only be "easily divided into discrete, measurable variables" (Leedy, 2005: 96) based upon historical data for a platform. Since this type of data was not available for the RMLV, data was collected from previous research efforts, AF and DoD policy, and historical data from comparable platforms, focusing on gaining increased insight from these sources rather than trying to collect quantitative data from a sample.

Data Analysis: The data analysis method in this study was partially subjective in nature, relying on inductive reasoning and synthesis to gather many specific observations from aircraft, EELV, ICBM, and Shuttle operations that led to inferences about the logistics support structure for the RMLV (Leedy, 2005: 95-96). However, manpower analysis also utilized a designed experiment approach to assessing the impact of individual factors on logistics manpower. This approach is described in greater detail in the Data Collection and Analysis Strategies section of this chapter.

The research method selected for this thesis, described in the following section, was uniquely tailored to the objective of determining the logistics ground support workforce for an RMLV fleet, and provided a solid analytical framework for conducting a thorough qualitative study.

An Analytical Framework for Projecting an RMLV Ground Support Workforce

The RMLV will be an AF asset and, as such, the support organization for the vehicle was developed in accordance with AF policy as defined by AF Policy Document 38-2, *Manpower*, and AF Instruction 38-201, *Determining Manpower Requirements*. The purpose of the guidance outlined in these documents is to ensure that AF units "successfully accomplish assigned missions using [the] minimum levels of manpower needed to effectively and efficiently execute missions" (Air Force, AFPD 38-2, 1995: 1). AFI 38-201 provided a step-by-step process by which to determine unit manpower requirements under this construct. These instructions, therefore, provided the analytical framework for this research project.

Identifying the Requirements.

The AF manpower requirements determination process begins with a well-defined mission requirement. This research began with a comparison of the MILEPOST model to the current AFSC structure in order to fully describe the RMLV support requirements and determine the capability of existing AFSCs to perform support operations. This enabled the selection of an appropriate manpower standard or alternate method of manpower requirements calculation in later steps of the research process.

Identifying the Organizational Structure.

The AF requires that "[o]rganizations with like responsibilities should have similar organizational structures" (Air Force, AFPD 38-1, 1996: 2.7). Based on the RMLV mission statement defined in Chapter I, Introduction, the research proceeded to determine the most appropriate AF organizational structure for an RMLV unit by comparing the RMLV mission to other AF organizational missions to discover the most appropriate structure for the new vehicle. This information also contributed to the selection of the most appropriate method of manpower requirements determination.

Determining the Manpower Requirements.

Methods of determining manpower requirements are established in AFI 38-201, *Determining Manpower Requirements*. These methods were explored, assessed, and applied in the next phase of research in order to staff the organization created in the previous section.

Assessing Life Cycle Cost and Training Implications.

Due to the unique nature of the RMLV, there may be ground logistics support shortfalls in the technical expertise of the current AF manpower pool. The final stage of this research addressed the training requirements and estimated life cycle costs generated by the manpower determination formed in the previous section.

Data Collection and Analysis Strategies

Initial data collection relied heavily upon the MILEPOST model and the developers' sources of RMLV information. To complete Step 1 in the research method, MILEPOST activities were compared to AF manpower resources as defined by AF guidance, developing a matrix assigning applicable AFSCs to each activity. For the purpose of projecting how AF manpower support may develop in response to the introduction of a new weapons system into the AF inventory, supplemental data was collected from observations during a tour of the B-2 maintenance facility and historical information on the development of the B-2 logistics support structure.

Data for the assessment of organizational structure was collected for agencies of interest primarily from their homepages or from the AF Portal. Organizational structure information was collected only from AF organizations because the RMLV unit will need to be organized in accordance with current AF policy.

In order to determine manpower requirements, procedural guidance was provided by the AF Materiel Command manpower office to determine the best method to project manpower requirements for the RMLV. Input data for the manpower numbers themselves was based on a synthesis of maintenance man-hour and other logistics support data from aircraft, ELVs and EELVs, the Shuttle, and ICBMs, as applicable, to maintain consistency with the MILEPOST model. As factors affecting manpower numbers were identified, they were assigned to a designed experiment where the response variable, Y, represents manpower and the total number of factors, *k*, are represented by individual variables, X_k. The generalized form of the experiment design is depicted in Table 3.

Table 3. Design of Experiment

Design Point	Factors		
	X_1	X_2	X_3
1	0	0	1
2	0	1	1
3	1	0	0
4	1	1	0
5	1	1	1

Factors are identified in Chapter VII, Manpower Assessment, and combinations of factors were sampled methodically to avoid the pitfall of "investigation of a handful of design points where many factors change simultaneously" (Sanchez, 2005: 71). This research assumed that there were no interactions among factors.

Finally, in evaluating training requirements and life cycle cost implications, historical data was collected from AF ground support training methods for new aircraft acquisitions and from DoD and AF policy on life cycle costing. By collecting multiple sources of data, the potential for bias in the analysis was reduced.

Assessing the Validity of the Research Method

In order to provide a useful tool to RMLV design and planning personnel, the research method outlined above must be validated. Quantitative researchers typically focus on ensuring the internal and external validity of their research design. Internal validity is defined as "the extent to which [the] design and the data it yields allow the researcher to draw accurate conclusions about cause-and-effect and other relationships within the data" (Leedy, 2005: 97). External validity is "the extent to which…results apply to situations beyond the study itself" (Leedy, 2005: 99). In the case of this research, external validity is not of great concern, as the results of the research are meant to provide insight into this specific problem. However, the research method modeled upon the AF process for determining manpower requirements should be proven to yield an accurate representation of what the true AF manpower requirements for support of an RMLV fleet will be.

Qualitative researchers rely on various methods of supporting validity of their findings. One method that supported the validity of this research was triangulation, or "comparing multiple data sources in search of common themes" (Leedy, 2005: 100). Additionally, following manpower determination methods outlined in AF policy ensured that the findings of this research were valid within the AF construct. Finally, sensitivity analysis was performed where applicable to account for as much variability in RMLV design as possible and maximize the utility of research findings to the RMLV development process.

Summary

In this chapter, a step-by-step qualitative research methodology was outlined. This method was based upon AF guidance for manpower determination and the synthesis of logistics support data from MILEPOST and its source platforms. Validity was achieved through synthesizing multiple data sources, following standardized AF procedures, and performing sensitivity analysis. The next chapter will begin execution of this research methodology by comparing MILEPOST activities to available AF technical expertise.

V. Analysis of Required Technical Expertise

Although the RMLV will differ considerably from any weapons system in the AF inventory, the AF manpower pool offered a great deal of applicable technical expertise. Because one of the objectives of RMLV design is to achieve “aircraft-like” operations, many of the activities identified in MILEPOST were based on aircraft operations, and AFSCs were applied directly. Additionally, activities that were derived from Shuttle or ICBM operations correlated strongly to AFSCs for Aircraft Maintenance or Space and Missile Operations and Maintenance. This chapter provides an introduction to the AFSCs that apply to ground support operations for the RMLV, identifies the correlation between those AFSCs and each stage of the regeneration process, and identifies any manpower shortfalls for the RMLV.

AFSC Analysis

The AF manpower structure currently accounts for many career fields for aircraft, space, and missile mission support. As established in Chapter II, Literature Review, any AFSCs related to Maintenance and Logistics Readiness formed the available support pool for RMLV regeneration activities. In order to specifically identify the career fields within these categories, the AF Officer and Enlisted Classification Directories, which list all approved AF standard AFSCs, were reviewed. AFSCs were divided into Direct Support and Indirect Support categories with respect to the RMLV. Additionally, it was noted that certain functions performed in support of mission requirements were not captured by one specific AFSC. Personnel performing these functions are critical to mission success, but they may be assigned from a variety of AFSCs, and were addressed under a third category, Cross-Functional Requirements. Finally, as specified in Chapter II, Literature Review, base support and infrastructure functions such as Civil Engineering and Security Forces were not addressed in this research.

Direct Support AFSCs.

Aircraft operations were a direct input to the development of the MILEPOST model, particularly in the Recovery and Ground Maintenance segments (Martindale, 2006; Pope, 2006). As a result, the Manned Aerospace Maintenance AFSCs listed in Table 4, developed to support AF aircraft, form part of the Direct Support manpower pool available for RMLV support.

Table 4. Manned Aerospace Maintenance AFSCs
(Air Force, AFOCD, 2006: 74; Air Force, AFECD, 2006: 71-99)

Manned Aerospace Maintenance				
	Management and Supervision		**Technicians**	
Manned Aerospace Maintenance	21AX	Maintenance Officer		
Avionics	2A600	Chief Enlisted Manager	2A0X1	Avionics Test Station and Components
	2A090	Superintendent		
Aerospace Maintenance	2A300	Chief Enlisted Manager	2A5X1	Aerospace Maintenance
	2A590	Superintendent	2A5X3	Integrated Avionics
Aerospace Propulsion	2A600	Chief Enlisted Manager	2A6X1	Propulsion
	2A691	Superintendent		
Aerospace Ground Equipment (AGE)	2A600	Chief Enlisted Manager	2A6X2	AGE
	2A692	Superintendent		
Aircraft Systems	2A600	Chief Enlisted Manager	2A6X4	Fuel Systems
	2A690	Superintendent	2A6X5	Hydraulics
			2A6X6	Electrical and Environmental
Aircraft Fabrication	2A600	Chief Enlisted Manager	2A7X1	Metals Technology
	2A790	Superintendent	2A7X2	NDI
			2A7X3	Structural Maintenance

In addition to personnel supporting Manned Aerospace Maintenance, Munitions and Weapons personnel may also contribute to Direct Support. As indicated in the Recovery segment of MILEPOST, the potential ability of the RMLV to return with

External Stores is equated to operations conducted when an F-16 lands with unexpended ordnance. This suggests that the functions of integrating and possibly unloading payloads and/or ordnance could be the responsibility of AF personnel with the AFSCs listed in Table 5.

Table 5. Munitions and Weapons AFSCs
(Air Force, AFOCD, 2006: 74; Air Force, AFECD, 2006: 153-157)

Munitions and Weapons				
	Management and Supervision		Technicians	
Munitions Systems	2W000	Chief Enlisted Manager	2W0X1	Munitions Systems
	2W091	Superintendent		
Aircraft Armament Systems	2W100	Chief Enlisted Manager	2W1X1	Aircraft Armament Systems
	2W191	Superintendent		

Finally, the AF Missile and Space Systems Maintenance Career Field offers capabilities that are well-suited to RMLV operations. AF personnel in this career field are responsible for the AF inventory of ICBMs, one of the platforms referenced in MILEPOST development. Additionally, one of the competency sets encompassed by this career field is the ability to "acquire, activate, and supervise assembly, transportation, maintenance, inspection, modification, and launch processing of spacelift boosters, satellites, and subsystems" (Air Force, AFECD, 2006: 125). The AFSCs in Table 6 are included in Missile and Space Systems Maintenance.

Table 6. Missile and Space Systems Maintenance AFSCs
(Air Force, AFOCD, 2006: 75; Air Force, AFECD, 2006: 125-130)

Missile and Space Systems Maintenance				
	Management and Supervision		Technicians	
	21MX	Missile Maintenance Officer		
Missile and Space Systems Maintenance	2M000	Chief Enlisted Manager	2M0X1	Missile and Space Electronic Maintenance
	2M090	Superintendent	2M0X2	Missile and Space Systems Maintenance

Indirect Support AFSCs.

In addition to the hands-on, technical operation and maintenance of each RMLV, indirect support functions in the categories of Logistics Ground Support, Maintenance Support and Other Ground Support will be required to support regeneration activities.

Logistics Ground Support AFSCs, listed in Table 7, perform the functions of an AF Logistics Readiness Squadron: procurement, storage, and distribution of supplies and fuels; development and supervision of logistics and support plans and agreements; packaging, handling, and shipment of freight; operation and maintenance of mission support vehicles; and inspection, preparation, and loading of freight onto military aircraft.

Table 7. Logistics Ground Support AFSCs
(Air Force, AFOCD, 2006: 77; Air Force AFECD, 2006: 119-124, 137-152)

Logistics Ground Support				
	Management and Supervision		Technicians	
Logistics Management	21RX	Logistics Readiness Officer		
Fuels Management	2F000	Chief Enlisted Manager	2F0X1	Fuels
	2F091	Superintendent		
Logistics Plans	2G000	Chief Enlisted Manager	2G0x1	Logistics Plans
	2G091	Superintendent		
Supply Management	2S000	Chief Enlisted Manager	2S0X1	Supply
	2S090	Superintendent		
Traffic Management	2T000	Chief Enlisted Manager	2T0X1	Traffic Management
	2T091	Superintendent		
Vehicle Maintenance Management	2T300	Chief Enlisted Manager	2T3X1	Vehicle/Vehicular Equip Maintenance
	2T391	Superintendent	2T3X2	Special Vehicle Maintenance
			2T3X4	General Purpose Vehicle Maintenance
			2T3X5	Vehicle Body Maintenance
			2T3X7	Vehicle Management and Analysis
Air Transportation	2T200	Chief Enlisted Manager	2T2X1	Air Transportation
	2T291	Superintendent		

Maintenance Support functions include analyzing repair data, scheduling maintenance activities, and managing maintenance facilities. Aircraft and space and missile Maintenance Support personnel are categorized under the AFSCs in Table 8.

Table 8. Maintenance Support AFSCs (Air Force, AFECD, 2006: 133-136, 125-130)

Maintenance Support				
	Management and Supervision		Technicians	
Maintenance Support	2R000	Chief Enlisted Manager	2R0X1	Maintenance Management Analysis
	2R091	Superintendent	2R1X1	Maintenance Management Production
Missile and Space Support	2M000	Chief Enlisted Manager	2M0X3	Missile and Space Facilities
	2M091	Superintendent		

In addition to Logistics and Maintenance Support, Other Ground Support functions are required to ensure a safe and successful mission. Safety personnel ensure the safety of the launch pad, vehicle, and all personnel involved in regeneration activities. Space Systems Operations personnel provide "space lift operations support to fulfill war fighting and national requirements" (Air Force, AFECD, 2006: 40). Precision Measurement Equipment Laboratory personnel provide "maintenance, modification, repair, calibration, and certification for test, measurement, and diagnostic equipment," (Air Force, AFECD, 2006: 132), which will be especially critical if the RMLV utilizes an IVHM system. AFSCs assigned to these specialties are listed in Table 9.

Table 9. Other Ground Support AFSCs
(Air Force, AFECD, 2006: 40, 59-60, 132; Air Force, AFOCD, 2006: 49)

Other Ground Support				
	Management and Supervision		Technicians	
Safety	1S000	Chief Enlisted Manager	1S0X1	Safety
	1S090	Superintendent		
Space Systems Operations	13SX	Space and Missile Operations Officer	1C6X1	Space Systems Operations
	1C600	Chief Enlisted Manager		
	1C691	Superintendent		
PMEL	2P000	Chief Enlisted Manager	2P0X1	PMEL
	2P091	Superintendent		

Cross-Functional Support.

Certain oversight and operations management positions authorized in an AF unit manpower structure are staffed based on a desired level of experience and excellence in an overall discipline, and may be performed by personnel with varying AFSCs within that discipline. The cross-functional nature of these positions prevents us from capturing them directly from the AFSC data, but they are critical to the mission success of any unit. These functions include: Quality Assurance (QA), Inspection, and Maintenance Operations Center (MOC).

<u>Quality Assurance (QA)</u>.

The QA function within the Maintenance Support discipline is responsible for managing an organization's Maintenance Standardization and Evaluation Program, through which "the quality of equipment and the proficiency of maintenance personnel" are evaluated (Air Force, AFI 21-101, 2006: 190). QA inspectors may be drawn from individual maintenance workcenters once they have six months of time in the unit, and are assigned to QA duties for 24 to 36 months (Air Force, AFI 21-101, 2006: 194). The QA function is aligned administratively within the Maintenance Operations Squadron, but reports directly to the Group Commander due to its unique role as the centralized management point for "identify[ing] underlying causes of poor quality in the maintenance production effort…and recommending corrective actions to supervisors" (Air Force, AFI 21-101, 2006: 190).

<u>Inspection</u>.

The consolidated Inspection function within a Logistics Readiness Squadron is managed by the Procedures and Accountability flight (Air Mobility

Command, AMCMD 716, 2004: 5), with the assistance of established Inspection functions within each of the functional areas. Specifically, the Supply discipline requires that qualified inspection personnel are assigned "as required to effect maximum surveillance through a minimum expenditure of effort in applying adequate identification, condition, and status markings to items received, stored, issued, and shipped" (Air Force, AFMAN 23-110, 2006: Vol 1, Part 1, 4-1). Within the Logistics Fuels specialty, a separate flight is established for Compliance and Environmental, responsible for evaluating the following: management effectiveness, administrative/LAN procedures, FISC accounting procedures, operator performance, ground safety and fire prevention, environmental compliance, corrosion control, care of equipment and facilities, training, [and] procedures for product quality" (Air Force, AFI 23-201, 2004: 53). Thus, for Logistics Support activities, the Inspection function will have to be taken into account in the manpower of each AFSC as well as the cross-functional oversight personnel in Procedures and Accountability.

<u>Maintenance Operations Center (MOC)</u>.

The MOC "monitors and coordinates sortie production, maintenance production, and execution of the flying and maintenance schedules while maintaining visibility of fleet health indicators" (Air Force, AFI 21-101, 2006: 143). Essentially, this center acts as the centralized control system for all maintenance activities, coordinating those activities to maximize flying missions. In order to be assigned to the MOC, the AFI requires that personnel "be experienced with the MIS [Maintenance Information System] and be qualified by formal training or experience on at least one of the assigned weapons systems" (Air Force, AFI 21-101, 2006: 145), which allows personnel from any AFSC to staff the center.

AFSC Assignment to MILEPOST Activities

While the current AF manpower structure incorporates a considerable variety of technical capabilities supporting air and space missions, it may still be insufficient for support of the unique hybrid characteristics of the RMLV. In order to determine the suitability of current AFSCs to RMLV ground support operations, a matrix was developed listing all of the RMLV regeneration activities defined in MILEPOST and an appropriate AFSC was assigned to each activity, drawing from the Direct Support, Indirect Support, and Cross-Functional AFSC pools identified above. The primary purpose of this matrix, located at Appendix A, was to identify those regeneration activities that require technical expertise that is wholly or partially absent from current AFSC resources.

As such, the matrix focused only on assigning at least one AFSC to each activity, and does not capture the entire scope of support required for any activity. For example, the activity in which the Launch Vehicle is towed to the maintenance hangar would be performed primarily by the Aerospace Ground Equipment troop operating the tow vehicle and the maintenance personnel acting as spotters, as depicted in Table 10.

Table 10. AFSC Assignment to MILEPOST Activity (Pope, 2006)

Ground Maintenance Operations			
Disconnection from the Launch Vehicle			
Activity	*Platform*	*AFSC*	*Comments*
Transport to Mx Bay	Aircraft	2A6X2, 2AXXX	AGE, spotters/wing-walkers (any maintenance AFSC)

However, assigning the 2A6X2 and 2AXXX AFSCs to this activity fails to capture the MOC personnel scheduling the maintenance bay and repair actions, the Missile and Space Facilities personnel responsible for the hangar, the Supply personnel responsible for providing spares for the RMLV and tow vehicle, the Vehicle Management personnel responsible for the maintenance of the tow vehicle, and the Quality Assurance and Inspection personnel overseeing all of these actions. As a result, this tool does not translate directly into manpower requirements for support of the RMLV. Total requirements will be determined in Chapter VII, Manpower Assessment, in accordance with AF policy.

Assumptions.

In populating the matrix, it was assumed that specific training for RMLV activities or support equipment operations would be provided in the same manner that it is provided for any new AF platform; therefore, as long as an AFSC met the general expertise requirement for the activity (propulsion, for example), the additional expertise required to repair an RMLV jet engine rather than an aircraft jet engine did not constitute a shortfall.

Additionally, I assumed that the integration configuration of the RMLV (horizontal or vertical) would impact the AFSCs responsible for integration operations. Given a horizontal integration scenario, I assumed that AGE personnel would maintain responsibility for maneuvering the RMLV, while Air Transportation personnel would be responsible for aligning and attaching the second stage and payload (whether pre-integrated or not). In the horizontal configuration, the first stage is easily accessible to Air Transportation personnel to maneuver and "load" the second stage and payload. This configuration allows responsibility for the “aircraft” stage and the “cargo” stages to reasonably remain within their current AFSC constructs. In a vertical integration scenario, however, the nature of the process necessitates that a single set of equipment be used to erect, align, and attach each stage. As a result, it does not make sense to assign the stages of integration to multiple AFSCs, and I assigned the entire operation to AGE. Under this scenario, Air Transportation personnel would be responsible for preintegrating the second stage and payload (if applicable), and delivering the second stage and payload to AGE for final integration. This assumption had little impact on identifying shortfalls, as both AFSCs are available and sufficient for these operations. However, the assignment choices will impact the Manpower Assessment in Chapter VII.

While the matrix verified that current AFSCs sufficiently capture many of the technical specialties required for RMLV ground operations, there are shortfalls in the AF manpower structure that will need to be addressed.

Shortfalls

Shortfalls identified in the matrix occurred in the Recovery and Pre-Launch Operations phases of MILEPOST. Maintenance activities exhibited no shortfalls because the systems contained within the RMLV (fuel systems, hydraulic systems, propulsion systems, structures) are also contained within AF aircraft and ICBMs. Recovery and Pre-Launch Operations, however, included several processes that differ significantly from similar operations performed on aircraft.

Shortfalls can be classified into two categories: Lack of Expertise and Lack of Experience. A Lack of Expertise shortfall occurs when an RMLV regeneration activity requires a skill set that is not required by any platform currently in the AF inventory.

Such a shortfall would require the addition of the entire skill set to a current AFSC or procurement of the required support through a contract. This type of shortfall is not historically unprecedented. When the B-2 was introduced into the AF inventory, the unique maintenance requirements generated by its Low Observable and Thermal Protection structural components required both specific training for personnel with the Structural Repair AFSC and contracted support from Northrop Grumman to ensure the continuity of maintenance operations (B-2 Visit, 2006). The training commitment for this type of shortfall may be significant due to the lack of previously existing, similar training. A Lack of Experience shortfall occurs when current AF weapons systems require some general level of knowledge that could be applied to the RMLV activity, but the scope of the RMLV activity is much greater than that currently experienced in the AF. A Lack of Experience shortfall can be reasonably solved through additional training.

Lack of Expertise Shortfalls.

Lack of Expertise shortfalls occurred primarily as a result of the unique propellant alternatives for the RMLV, and the hazardous conditions that can result from their use. Hazardous Gas Purge, Coolant Ground Support Equipment, Vaccuum Vent Duct Inerting, Load Hypergolic Fuel, and Load RP-1 Fuel MILEPOST activities all require technical expertise beyond that currently inherent to any AFSC.

<u>Hazardous Gas Purge</u>.

The propellants utilized by the launch vehicle have the potential to create hazardous gas conditions within the RMLV, requiring that the vehicle be purged upon landing for the safety of personnel involved in the regeneration activities.

Coolant Ground Support Equipment (GSE).

The extreme heat generated by the high speed takeoff and reentry into the earth's atmosphere require that the RMLV be hooked up to coolant support immediately upon landing. The Coolant GSE maintains a suitable temperature for electronic and control systems as the vehicle's onboard cooling system is powering down (Martindale, 2006: 10).

Tank Vent RMLV Main Engine.

This process addresses the "venting of fuels and fumes from the RMLV main engine (ME) tanks to ensure potential hazards are eliminated prior to the vehicle entering the maintenance facility" (Martindale, 2006: 36).

Lack of Experience Shortfalls.

The Lack of Experience shortfalls occurred in safing and fueling operations that are commonly performed on AF aircraft. The RMLV, however, introduces new and more hazardous materials to the operations.

Drag Chutes.

This operation involves safing the drag chute pyrotechnics. While the F-104A employed drag chutes, it is no longer active in the AF inventory (F104A, 2007). The B-52 maintains the capability to deploy drag chutes for landing, but this is not part of normal operating procedures (What a Drag, 2007). However, pyrotechnics are used in ejection seats, and this activity simply reflects a greater scope of a similar operation.

LOX Safing.

In addition to the pyrotechnics, the ground crew must safe the LOX tanks to "ensure no venting occurs which could produce a fire hazard condition" (Martindale, 2006: 32). While utilized in small quantities as a crew oxygen source, LOX is not used as a major fuel source in AF weapons systems, so the presence of LOX in these quantities constitutes a shortfall in experience.

Hypergolic Leak Detection.

If the RMLV design includes hypergolic fuels, leak detection will be part of the safety assessment upon landing. The hypergolic fuel hydrazine is used in small quantities in the Emergency Power Unit of the F-16. As this unit is only used in emergencies, AF personnel have limited exposure to hydrazine. The RMLV will require greater experience in detecting and managing hypergolic fuel leaks.

Load Hypergolic Fuel/Load RP-1 fuel.

Neither of these fuel alternatives is common to current AF platforms.

Chill and Load LOX and Fuel.

"RMLVs require both fuel and oxidizer for engine operation" (Stiegelmeier, 2006: 34). This propellant combination is not common to any other AF airframe, and Fuels personnel will require additional qualification and training to handle and distribute this fuel type.

Summary

All of the ground support activities identified in MILEPOST can be supported by the AFSC structure in its current form; however, as with the introduction of any new platform, there will be shortfalls in expertise and experience. These shortfalls will have to be addressed in a training program; training implications will be discussed in Chapter VIII, Conclusions and Future Research.

VI. Analysis of Organizational Structure

Air Force Policy Document 38-1, Organization, states that the principal characteristics desired in Air Force organizations are mission-orientation, unambiguous command, decentralization, agility, flexibility, simplicity, and standardization (Air Force, AFPD 38-1, 1996: 1). Air Force Policy specifically requires that "[o]rganizations with like responsibilities should have similar organizational structures" (Air Force, AFPD 38-1, 1996: 1). The key to assessing the future organizational structure required to support an RMLV fleet, then, is to determine what current Air Force organization possesses "like responsibilities" to the RMLV mission, and model the organizational structure on that example. Because the RMLV is not exactly like anything in the current inventory, but is a synthesis of a space mission with the desire for an aircraft-like operational capacity, we will examine the Air Force organizational structures of operational units within AF Space Command (AFSPC), Air Combat Command (ACC), and Air Mobility Command (AMC) to determine which aspects of each structure appear to be most appropriate to the RMLV mission.

In Chapter I, Introduction, the RMLV mission was defined as: to preserve the nation's freedom of operations in space by providing dependable, responsive spacelift capability to deliver payloads supporting deployment, sustainment, augmentation, and operations missions within hours or days of initial tasking. The following sections summarize a comparison of this mission statement to the mission statements of Air Force organizations at the MAJCOM, Wing, and Unit levels to capture similarities and determine the organizational structure that will define the RMLV fleet. Additionally, similarities and differences in the maintenance and ground support missions will be addressed to further pinpoint the optimal logistics support structure for the RMLV.

MAJCOM-Level Evaluation

AFSPC would appear to be the natural organizational location for an RMLV wing. The mission of AFSPC is “to defend the United States through the control and exploitation of space” (Air Force Space Command, 2006). AFSPC is a combat-oriented command, seeking to “provide a full-spectrum Space Combat Command preeminent in the application of space power for national security and joint warfare” through the application of four strategic focal points: securing the space domain and providing space combat capabilities to warfighters, maintaining deterrent capabilities and pursuing new triad capabilities, excelling in space acquisition, and providing world-class professional development and quality-of-life support to AFSPC personnel (Air Force Space Command, 2006). The RMLV, as currently envisioned, is a combat support vehicle, and seems to fit within the AFSPC mission and strategic focus only in that its payload may provide combat, deterrent, or triad capabilities, and it would be obtained through the space acquisition process. However, AFSPC assets do include all of the current AF space and missile launch vehicles, so that while the mission statement does not reflect similar organizational responsibilities, those responsibilities are supported by assets within the AFSPC organization. This will be examined in greater detail at the Wing and Unit levels, as we evaluate the missions of Space Launch Wings and their sub-organizations.

Air Combat Command encompasses the AF’s fighter, bomber, reconnaissance, battle-management, and electronic-combat platforms, and is the “primary force provider of combat airpower to America's warfighting commands” in support of global implementation of national security strategy (Air Combat Command, 2006). ACC also provides "command, control, communications and intelligence systems, and conducts global information operations" as well as maintaining "combat-ready forces for rapid deployment and employment while ensuring strategic air defense forces are ready to meet the challenges of peacetime air sovereignty and wartime air defense" (Air Combat Command, 2006). ACC assets are highly-deployed, providing support and augmentation to geographical commands and AOR commanders. The RMLV mission includes launching and maintaining satellites that directly support information operations for the warfighter, as well as providing deterrence, response, or denial of access against agents that seek to challenge our peacetime space sovereignty or wartime space defense. In these respects, the mission of the RMLV fleet is similar to that of ACC assets; again, however, the vehicles themselves simply provide the delivery mechanism for the payloads that directly carry out these operations. In terms of ground support operations, previous research has identified the B-2 as a platform that is "similar in many ways to the launch vehicle," and as a result the B-2 was used as a source of input for constructing the Ground Maintenance Operations segment of MILEPOST (Pope, 2006: 22). This constitutes a basis for "like responsibilities," particularly regarding logistics support, and indicates that an appropriate organizational structure may be similar to an ACC bomber wing. We will explore the bomber mission comparison in greater detail at the Wing and Unit levels. Finally, since the RMLV is to be unmanned, Unmanned Aerial Vehicles (UAVs) like the Predator and Global Hawk, both ACC assets due to their reconnaissance mission, may provide a relevant comparison platform for organizational structures.

These organizations, as well, will be explored in further detail at the Wing and Unit levels.

Finally, the spacelift function of the RMLV fleet would seem to align with the Air Mobility Command’s mission to provide “rapid, global mobility and sustainment for America's armed forces” (Air Mobility Command, 2006). As AMC recognizes, “without the capability to project forces, there is no conventional deterrent” (Air Mobility Command, 2006). The same will be true in space, and the RMLV fleet will provide the asset projection capability that enables its mission focus of deterrence. Additionally, the projected use of the RMLV fleet to provide space cargo-delivery capability, and even future space refueling operations as part of satellite maintenance, bears significant similarity to AMC’s fleets of airlifters and air refuelers. AMC is focused on providing a “rapid, tailored response” (Air Mobility Command, 2006) that directly correlates with the RMLV requirement for responsiveness, and AMC’s combat support role is similar to the role we expect RMLVs to play in the combat environment. Based on these similarities, we will continue to assess the applicability of an AMC organizational structure at the Wing level.

The mission of the RMLV contains elements that align it with portions of each of the operational MAJCOMs examined. While the mission statement bears the greatest direct resemblance to the mission and operations of an AMC wing, the RMLV is a space vehicle like those assigned to AFSPC, and it also supports reconnaissance and information support missions that traditionally fall under ACC. Additionally, the RMLV maintenance requirements bear significant similarities to B-2 logistics support. In the next section, an examination of individual Wing missions within these MAJCOMs will attempt to narrow the organizational correlations to the RMLV.

Wing-Level Evaluation

Since AFSPC, ACC, and AMC missions all correlated in some manner to the RMLV mission, this section will provide an evaluation of aircraft Wings within all three MAJCOMs. Additionally, while the AF does not operate a Wing for any unmanned aircraft, the section will conclude with an examination of UAV Squadrons for similarities to the RMLV.

Air Force Space Command Wings.

AFSPC is made up of Space Wings, which encompass both missile and space launch assets. The mission statements of both types of Space Wing will be reviewed to determine similarities to the RMLV mission.

Missile Wings.

The mission of the 90th Space Wing at F.E. Warren AFB, Wyoming, is to "defend America with the world's premier combat ready ICBM force: On time, Every time, Any time" (90th Space Wing Mission, 2006). In like manner, the mission of the 91st Space Wing at Minot AFB, North Dakota, is to "defend the United States with safe, secure intercontinental ballistic missiles, ready to immediately put bombs on target" (Rough Riders, 2006). The nature of the ICBM mission requires maintaining a constant state of readiness to launch, without actually launching. Unlike an aircraft wing, ICBMs are not regularly launched and recovered, though they will be frequently tested for system readiness. At current Shuttle launch rates, which have historically achieved a maximum of seven to eight flights per year (McCleskey, 2005: 3), RMLVs would not often be actively employed, but primarily maintained in a constant state of readiness to respond to a space launch need. In this sense, the RMLV mission could be very much like the mission at an ICBM wing, and the ICBM maintenance support structure may provide a comparable foundation for the RMLV logistics support organization, which will be further explored at the Unit level.

Space Launch Wings.

At the 45th Space Wing, Patrick AFB, Florida, host unit to Cape Canaveral Air Force Station, the mission is to "assure access to the high frontier and to support global operations" (45th Space Wing, 2006). Again, in a similar fashion, the mission of the 30th Space Wing, Vandenberg AFB, California, is to "defend the United States through Launch, Range, and Expeditionary Operations" (30th Space Wing Mission & Vision, 2006). Cape Canaveral, as the launch site for the Space Shuttle, the nation's only current form of reusable launch vehicle, provides a potential for commonality that does not exist with any other AF organizational structure. In fact, as stated in the Introduction, Cape Canaveral and Vandenberg have been identified as the two most likely bases of operation for the RMLV fleet. Additionally, the mission of providing space access to defend the US and provide global support to our forces is consistent with the RMLV operational responsibilities. However, there are key differences that suggest that the logistics support organizations at these two bases will not provide a sufficient framework for RMLV organizations. First, at Cape Canaveral, the United Space Alliance exercises "prime responsibility for the day-to-day operations of NASA's Space Shuttle Program," while RMLV support is assumed to be a blue-suit operation (USA History, 2006). Second, at Vandenberg, AF launch missions are accomplished through EELV Launch

Capability (ELC) and Launch Services (ELS) contracts, in which the contractor provides "engineering; program management; launch and range site activities; and mission integration" for individual missions which are purchased two years in advance of launch (Air Force Awards EELV Funding, 2006). As a result, neither of these Wings, while possessing similar mission responsibilities to the RMLV, will provide an accurate foundation for its logistics manpower support structure.

Air Combat Command Wings.

As indicated by the missions outlined at the MAJCOM level, ACC Wings support a wide variety of combat and direct combat support missions. Specifically, in this section, Fighter and Bomber Wings will be evaluated for similarities to the RMLV mission.

Fighter Wings.

While the 1st Fighter Wing, Langley AFB, Virginia "trains, organizes and equips expeditionary Airmen; [to] deploy, fight and win" (1st Fighter Wing, 2006), the 4th Fighter Wing, Seymour Johnson AFB, North Carolina "provides worldwide deployable aircraft and personnel capable of executing combat missions in support of the Aerospace Expeditionary Force" (Seymour Johnson AFB Mission, 2006). Similarly, at Eglin AFB, Shaw AFB, Cannon AFB, Holloman AFB, Mountain Home AFB, and Hill AFB, the mission focus is on force projection, expeditionary operations, and global, rapid deployment capability (33rd Fighter Wing, 2006; Shaw AFB Mission, 2006; 27th Fighter Wing, 2006; Holloman AFB Mission, 2006; 366th Fighter Wing Mission, 2006; 388th Fighter Wing Mission, 2006). Additionally, while Fighter aircraft inventories are large, with multiple squadrons in a wing, the RMLV fleet will be small, a single unit with only six vehicles. The logistics support organization for a Fighter Wing has a vastly different magnitude and mission focus than what will be required for the RMLV.

Bomber Wings.

Bomber Wings provide some greater degree of similarity to the RMLV. While platforms like the B-1 are primarily expeditionary (Dyess AFB Mission, 2006; Ellsworth AFB Mission, 2006), long-range bombers like the B-52s focus on the ability "to provide responsive, flexible and accurate" support (2nd Bomb Wing Mission, Vision & Vector, 2006) or on providing the capability to deliver a payload anywhere in the world (Whiteman AFB Mission, 2006). This mission is more similar to the RMLV responsibility to provide responsive spacelift to deliver payloads in response to global warfighter requirements. Specifically, the B-2 logistics support infrastructure encounters unique challenges that are similar to the maintenance requirements of the RMLV. First, the B-2 structural elements have Low Observable (LO) components, including thermal protection tiles, that require special maintenance procedures that are not common to other airframes (B-2 Spirit, 2006; Visit, 2006). In fact, much like the Shuttle's Thermal Protection System tiles account for 30% of its maintenance man-hours (McCleskey, 2005: 38), the B-2's LO system is its most maintenance-intensive. A 2006 program that replaced 60% of the LO material with a new, more maintenance-friendly Alternate High Frequency Material yielded a 50% decrease in total maintenance man-hour requirements (Boston Program, 2006). Additionally, with only 21 aircraft in the AF inventory (B-2 Spirit, 2006), maintainers face a unique challenge: maintenance problems simply do not occur with enough frequency for personnel to achieve the same level of proficiency as in larger units. This problem is compounded by the typical turnover rate of AF personnel, and introduces inefficiency into maintenance operations (Visit, 2006). The B-2 maintenance unit overcame this obstacle by partnering with Northrop Grumman contractors, who had achieved a greater level of proficiency by performing the same type of activities repetitively on the production line (Visit, 2006). The same maintenance challenges faced by the B-2 will be obstacles for the RMLV, with its unique systems requirements and small fleet size. As a result, the B-2 logistics support infrastructure will provide a sound basis for developing an RMLV ground support organization.

Air Mobility Command Wings.

Air Mobility Command provides for all of the airlift and air refueling requirements of the armed forces. In this section, both Airlift and Air Refueling Wings will be examined, as each function is part of the proposed RMLV mission.

Airlift Wings.

Airlift Wings utilize a wide variety of platforms in the performance of their mission. Some, like the C-20 and C-21, are specialized to aeromedical evacuation or support of high-ranking government officials (C-20, 2006; C-21, 2006), while others, like the C-130, C-17, and C-5, specialize in the movement of cargo in support of global missions. In this section, C-130, C-17, and C-5 Wings will be the primary focus due to the more generalized nature of their missions. Pope AFB, with its fleet of C-130s, "is capable of deploying a self-sustaining war fighting package anywhere in the world at a moment's notice, to form our nation's premiere forced entry capability with the United States Army," and also deploys to provide intra-theater airlift for global areas of operation (43rd Airlift Wing, 2006). This mission lacks similarity to the RMLV mission, which does not include a focus on forced entry capability or deployment to theater. The

62nd Airlift Wing, on the other hand, utilizes C-17s to "deliver global airlift, focused logistics, and agile combat support for America" (62nd Airlift Wing, 2006). This mission is similar in nature to that of the RMLV, which carries payloads to provide spacelift, space logistics support, and combat support capabilities. However, the specifics of the mission requirements will differ. The 437th Airlift Wing at Charleston AFB, also operating C-17s, is tasked to "provide for the airlift of troops and passengers, military equipment, cargo and aeromedical airlift and to participate in operations involving the airland or airdrop of troops, equipment and supplies when required" (437th Airlift Wing, 2006). C-5s out of Dover AFB are focused on "providing worldwide movement of outsized cargo and personnel on scheduled, special assignment, exercise and contingency airlift missions" (436th Airlift Wing, 2006). The RMLV, as currently conceived, will primarily deliver equipment and cargo payloads, with little focus at this time on personnel movement. Payloads will be delivered to provide a space capability, rather than to transport personnel and cargo into a theater of operations. In summary, while the spacelift function is a critical aspect of the RMLV mission, the mission specifics of airlift aircraft do not provide a strong basis for comparison for a future RMLV unit.

<u>Air Refueling Wings.</u>

Air Force air refueling is provided by KC-10 and KC-135 aircraft, operating as part of Air Mobility Wings or Air Refueling Wings, respectively. In their role as refuelers, both KC-10 units and KC-135 wings recognize their primary contribution to providing "global reach by conducting air refueling and airlift where and when needed" (McConnell AFB, 2006). While space refueling may be part of the RMLV mission of satellite maintenance, there is not a great enough similarity for a tanker unit to provide a useable framework for an RMLV unit.

UAV Squadrons.

The MQ-1, Predator, is classified as a UAV, but consists of an entire system of equipment including “four aircraft (with sensors), a ground control station, a Predator Primary Satellite Link, and approximately 55 personnel for deployed 24-hour operations” (MQ-1 Predator, 2006). As such, it does not provide a high degree of similarity to the RMLV, regardless of the overlapping reconnaissance mission characteristics. The RQ-4A, Global Hawk, is an unmanned reconnaissance platform that, once programmed with mission data, can “autonomously taxi, take off, fly, remain on station capturing imagery, return and land” (Global Hawk, 2006). Similarly, the RMLV will be expected to take off, fly to disengagement altitude, return and land with no crew onboard. The Global Hawk is still undergoing testing, but one operational squadron is assigned at Beale AFB, tasked to operate and maintain “deployable, long-endurance RQ-4A aircraft and ground-control elements to fulfill training and operational requirements generated by the Joint Chiefs of Staff in support of unified commanders and the Secretary of Defense” (12^{th} Reconnaissance Squadron, 2006). Like the RMLV, fleet size is small, and results in a single squadron of vehicles assigned to a wing along with U-2 reconnaissance aircraft. Due to the similarities in operational profile, combat support mission, and small fleet size, the Global Hawk Squadron provides a comparable organizational framework for an RMLV unit, and will be explored in further detail at the Unit level.

Unit-Level Evaluation

Up to this point, examination of the mission statements of various wing-level organizations has revealed that an ICBM Wing, a B-2 Bomber Wing, and a Global Hawk Squadron all provide reasonable foundations for modeling an RMLV logistics support structure, while Space Launch Wings, Fighter Wings, Airlift Wings, and Air Refueling Wings do not. In this section, the logistics support units for these wings will be examined and evaluated to arrive at a final estimation of an RMLV organizational structure.

ICBM Units.

The 90th Space Wing at F.E. Warren AFB is made up of the following groups: Operations Group, Maintenance Group, Security Forces Group, Mission Support Group, and Medical Group (Units at F.E. Warren AFB, 2006). Of these, the Maintenance Group, Security Forces Group, and Mission Support Group include functions that may apply to logistics ground support requirements for an RMLV. The high value of the RMLV and its critical role in providing for the national defense initially seem to justify a Security Forces Group, rather than the typical Squadron. However, the specific role of the 90th Security Forces Group is to protect “15 Missile Alert Facilities and 150 Minuteman III Intercontinental Ballistic Missiles on 24-hour alert throughout a 12,600 square mile area spanning three states” (Units at F.E. Warren AFB, 2006). The magnitude of this mission justifies a separate Security Forces Group, and will not be present in an RMLV unit. The 90th Maintenance Group works “24 hours a day, 365 days a year to ensure the world’s most powerful ICBM force remains safe, reliable, and effective” (Units at F.E. Warren AFB, 2006), and is made up of a Missile Maintenance Squadron and Maintenance Operations Squadron (90th Space Wing, 2006). This degree of support is what will be expected from an RMLV Maintenance Group. The 90th Logistics Readiness Squadron within the Mission Support Group is another agency that would be expected to provide ground support in an RMLV unit.

The 91st Space Wing at Minot AFB, in comparison, is comprised of an Operations Group, Maintenance Group, and Security Forces Group (Rough Riders, 2006). The 91st Maintenance Group provides both maintenance and logistics support to the ICBM fleet through the Missile Maintenance Squadron and the Maintenance Operations Squadron (Rough Riders, 2006). Due to the small RMLV fleet size, it can be expected that a single group could provide both maintenance and logistics support, and the RMLV ground support organization modeled after an ICBM Wing would be constructed as depicted in Figure 27.

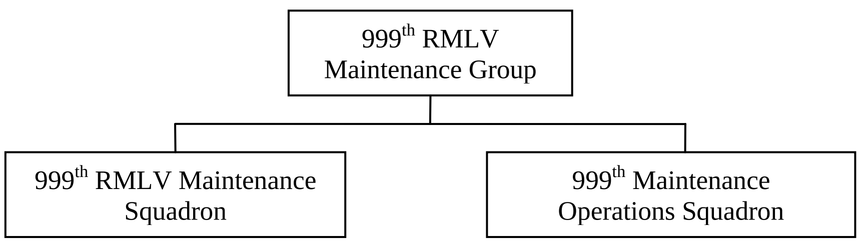

Figure 27. RMLV Organization Based on ICBM Structure

Unlike Maintenance Groups supporting aircraft, this organization does not include a Maintenance Squadron, which performs backshop maintenance support. While this function is not necessary for ICBM support, it is assumed by the MILEPOST model to be necessary for RMLV support, as the model includes activities such as wheel and tire replacement and engine maintenance that will occur in backshops. Additionally, there is no Munitions Squadron as is present in the aircraft units that follow; however, a similar Squadron will likely be required by the RMLV due to the presence of an externally-attached payload on every mission. As a result, although the ICBM maintenance operations tempo may be similar to that expected for the RMLV, the organizational structure of the logistics elements is not sufficient to support the RMLV mission.

B-2 Units.

The 509th Bomb Wing at Whiteman AFB is made up of an Operations Group, Maintenance Group, Mission Support Group, and Medical Group (Units at Whiteman AFB, 2006). As with the Space Wings, the Maintenance Group and Mission Support Group contain functions that align with logistics ground support. The 509th Maintenance Group is comprised of a Munitions Squadron, Maintenance Operations Squadron, Maintenance Squadron, and Aircraft Maintenance Squadron (Units at Whiteman AFB, 2006). While the Munitions Squadron, which handles the bombs loaded onto the B-2, does not directly correlate to the RMLV, there may be a similar squadron that handles payloads. Also as with the Space Wings, the Logistics Readiness Squadron within the Mission Support Group would provide some ground support functions. If structured like a B-2 Wing, the RMLV organization would require the units shown in Figure 28.

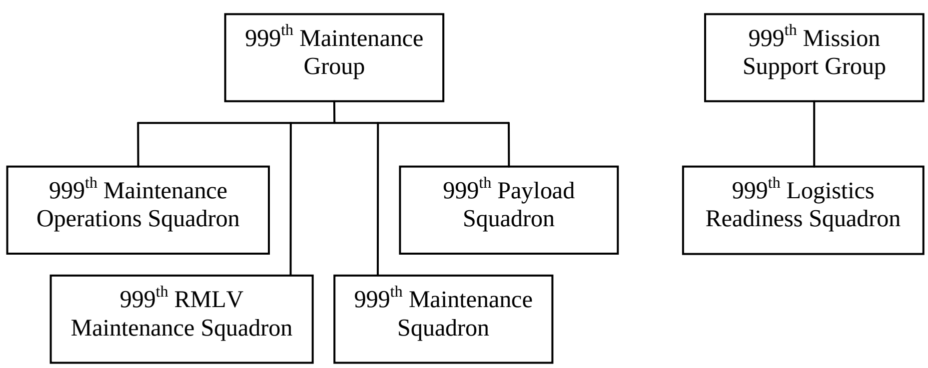

Figure 28. RMLV Organization Based on B-2 Structure

The organization supporting the B-2 includes all of the elements required to perform MILEPOST regeneration activities for the RMLV, and does not exhibit any functional activities that differ significantly from the RMLV mission or envisioned operations. As such, the B-2 organizational structure is a viable candidate for RMLV organizational development.

UAV Units.

The 9th Reconnaissance Wing at Beale AFB is structured like the B-2 Wing, with an Operations Group, Maintenance Group, Mission Support Group, and Medical Group (Units at Beale AFB, 2006). Again, the 9th Mission Support Group includes a Logistics Readiness Squadron which would support ground operations, and the 9th Maintenance Group is comprised of a Maintenance Squadron, Aircraft Maintenance Squadron, Maintenance Operations Squadron, and Munitions Squadron (Units at Beale AFB, 2006). The RQ-4A, Global Hawk, is flown by the 12th Reconnaissance Squadron, one of four flying squadrons within the Operations Group (Units at Beale AFB, 2006). All four flying squadrons are supported by the Maintenance Group, so its mission requires "providing worldwide maintenance support for the U-2, T-38, and RQ-4 aircraft" (9th Maintenance Group, 2006). As such, the structure for logistics support, depicted in Figure 29, would include the same components as a B-2 wing, but these units would provide maintenance support to the RMLV fleet as one of several operational squadrons.

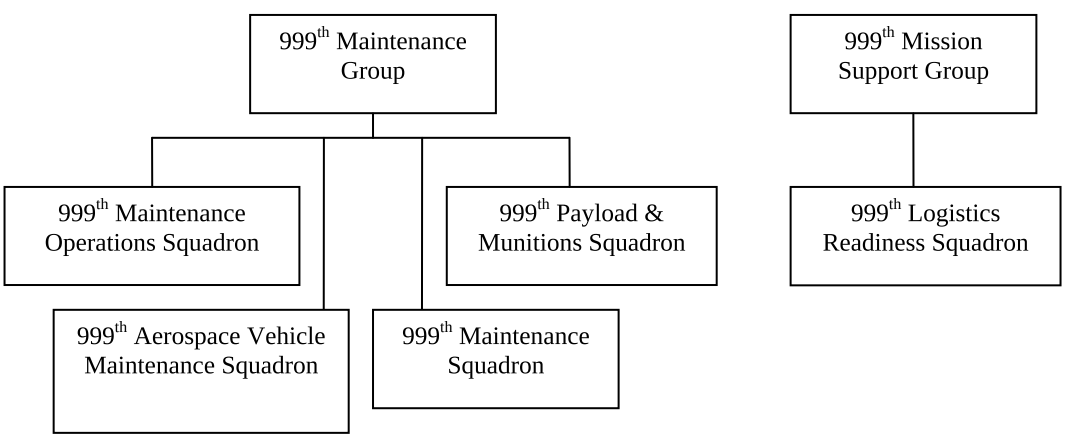

Figure 29. RMLV Organization Based on UAV Structure

The logistics support structures of the UAV and the B-2 are essentially the same; the only difference is whether the same organization will be supporting other aerospace platforms, or will be dedicated to RMLV support. This will be determined by the aerospace platforms currently on-station at the RMLV's future base of operations, which will be discussed in the next section.

Evaluation of Operational Locations

Recall from Chapter I, Introduction, that the RMLV fleet is likely to be stationed either at Vandenberg AFB or Cape Canaveral AFS, a unit at Patrick AFB, both of which are currently operational Space Wings. Each of these locations has been found in this chapter to be lacking the "like responsibilities" necessary to establish the RMLV organization under its current structure. More appropriate organizational structures have been identified from a B-2 Wing and a Reconnaissance Wing supporting the Global Hawk Squadron. This section will explore how an appropriate RMLV logistics ground support organization may fit into the Space Wing structures at Patrick AFB or Vandenberg AFB.

Patrick AFB.

The 45th Space Wing at Patrick AFB is made up of a Medical Group, Mission Support Group, Operations Group, and Launch Group. Space Shuttle maintenance is performed through a contract with USA, so no Maintenance Group is currently present. Within the Launch Group, the 1st Space Launch Squadron is responsible for Delta II launch vehicles while the 5th Space Launch Squadron supports the Atlas V and Delta IV vehicles (45th Launch Group, 2006). The Reusable Military Launch Vehicles would operate as a separate squadron within this Launch Group. The resulting wing structure at Patrick AFB is depicted in Figure 30 (changes denoted by dashed lines and italics):

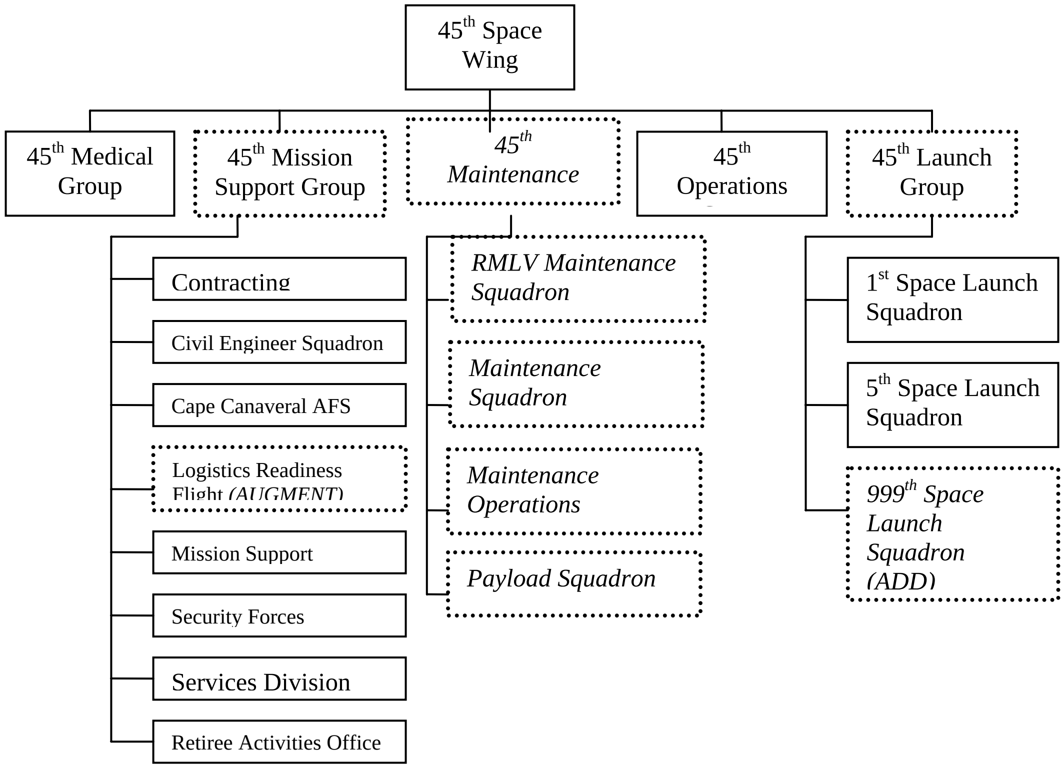

Figure 30. RMLV Organization at Patrick AFB (Units at Patrick AFB, 2006)

As indicated by the organizational chart, supporting an RMLV fleet at Patrick AFB would entail adding a Launch Squadron, increasing the size of the Logistics Readiness Flight to support the new Squadron, and adding a Maintenance Group. Based on the fact that all other aerospace platforms on-station receive logistics ground support through contractor operations and will not share ground support resources with the RMLV, the B-2 logistics support organization will provide the best frame of reference for RMLV operations

Vandenberg AFB.

Like Patrick AFB, the 30th Space Wing at Vandenberg AFB is made up of four groups, with no Maintenance Group, since their primary mission focus is on expendable launch vehicles. Within the Operations Group, Vandenberg AFB operates a Launch Squadron for the EELV program, a Launch Support Squadron, and the 1st Air and Space Test Squadron (ASTS) (Units at Vandenberg AFB, 2006). The ASTS is the only organization within the AF with the capability for "full service Air Force Developmental Test and Evaluation…for missiles, launch vehicles and payload/launch vehicle integration" (30th Launch Group, 2006). As such, this squadron may provide a reasonable initial organizational location for the RMLV, with the eventual development of a second Launch Squadron within the Operations Group. An organizational structure incorporating the RMLV fleet into the 30th Space Wing would be similar to that at Patrick AFB, and is described in Figure 31 (changes denoted by dashed lines and italics):

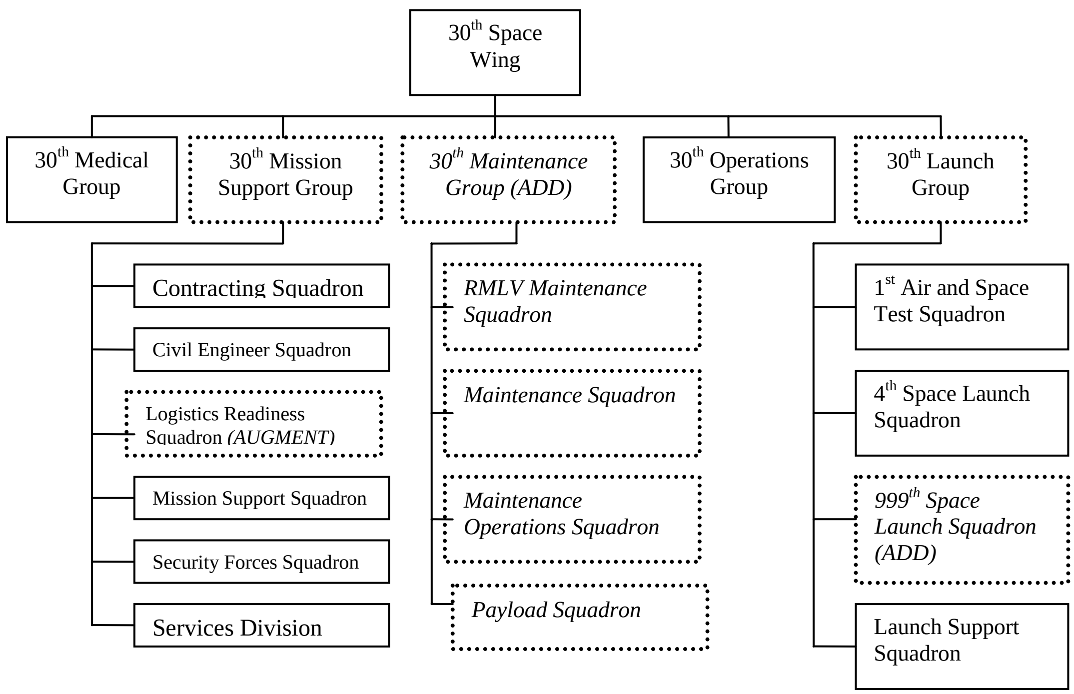

Figure 31. RMLV Organization at Vandenberg AFB (Units at Vandenberg AFB, 2006)

As at Patrick AFB, the addition of the RMLV fleet to the 30th Space Wing would require the addition of a Launch Squadron, the augmentation of the Logistics Readiness Squadron, and the addition of a Maintenance Group. Again, the EELVs receive logistics ground support through contractor operations, so the B-2 organizational structure would provide the most accurate framework for RMLV ground support. The organizational benefit of locating at Vandenberg AFB is the presence of the ASTS to support the RMLV as a newly-developed vehicle; however, the impact on organizational structure is the same at either location.

Summary

The objective of this chapter was to determine a currently-existing AF organizational structure for logistics support units that best matched the mission profile of the RMLV. This objective was approached through a methodical process of comparing mission statements at the MAJCOM and Wing levels to identify "like responsibilities" that would distinguish certain organizations as suitable models for RMLV organization. In addition to the organization and vehicle mission statements, an assessment of similarities in the logistics support mission was factored into the evaluation of each organization. As a result of these comparisons, an ICBM Wing, a B-2 Wing, and a Reconnaissance Wing supporting a UAV Squadron were each identified as providing a justifiable basis for RMLV ground support organization.

Following this determination, the logistics support units for each of these wings were assessed to note similarities and differences in structure. Finally, an assessment of the two proposed RMLV operating locations was conducted to determine the impact of incorporating the RMLV fleet and it logistics support units into the existing organizations. The conclusion of this evaluation is that RMLV logistics ground support, at either of the assumed operating locations, will consist of:

1. A Logistics Readiness Squadron under the Mission Support Group that is an augmented version of the unit already established in the Wing
2. A Maintenance Group, added to the Wing structure, made up of an RMLV Maintenance Squadron for flightline support, a Maintenance Squadron for backshop support, a Maintenance Operations Squadron, and a Munitions Squadron in accordance with B-2 organizational model.

The manning implications of this organizational structure will be analyzed in the following chapter.

VII. Manpower Assessment

In accordance with AF procedures, both LCOM and AFMS data were utilized to determine RMLV manpower requirements. Because logistics support functions are based in part on the size of the maintenance mission supported, total maintenance manpower requirements were calculated first. Based on the results of this assessment, calculations were performed for supporting logistics functions such as supply and transportation. The manpower requirements derived in this chapter were, of necessity, based upon a series of comparisons rather than on historical man-hour data. First, existing LCOM results from the 2005 B-2 LCOM analysis[2] were used as a framework for the development of maintenance manpower requirements. Since UAVs provide insight into support for unmanned platforms, manpower information from a UAV organization was used to provide comparison data to further refine workcenter estimates as necessary. In order to calculate total maintenance requirements, parametric relationships were established based on the relative contribution of individual workcenters to total aircraft and Shuttle maintenance requirements, relative vehicle complexity and fleet size, and relative surface area. Since the parametric relationships were estimates, sensitivity analysis was performed to account for a range of possible values. To calculate the remaining ground support workforce requirements, AF Manpower Standards were applied for supply, fuels, and transportation functions, again utilizing parametric relationships and sensitivity analysis as necessary. The chapter concludes with a range of the total number of personnel required to support RMLV regeneration activities.

[2] The results of the 2005 LCOM analysis are an input to determining manpower requirements, and do not directly reflect Unit Manning Document authorizations. Additionally, LCOM manpower numbers are intended specifically to support the requirements of the input scenario; this scenario, not current daily operations, forms the basis for comparison to project RMLV requirements.

B-2 LCOM Analysis 2005

The B-2 LCOM study divides the 509th Maintenance Group into five major sub-organizations: Group Staff Agencies, Aircraft Maintenance Squadron, Maintenance Squadron, Maintenance Operations Squadron, and Munitions Squadron. Figure 32 depicts the organizational structure in greater detail.

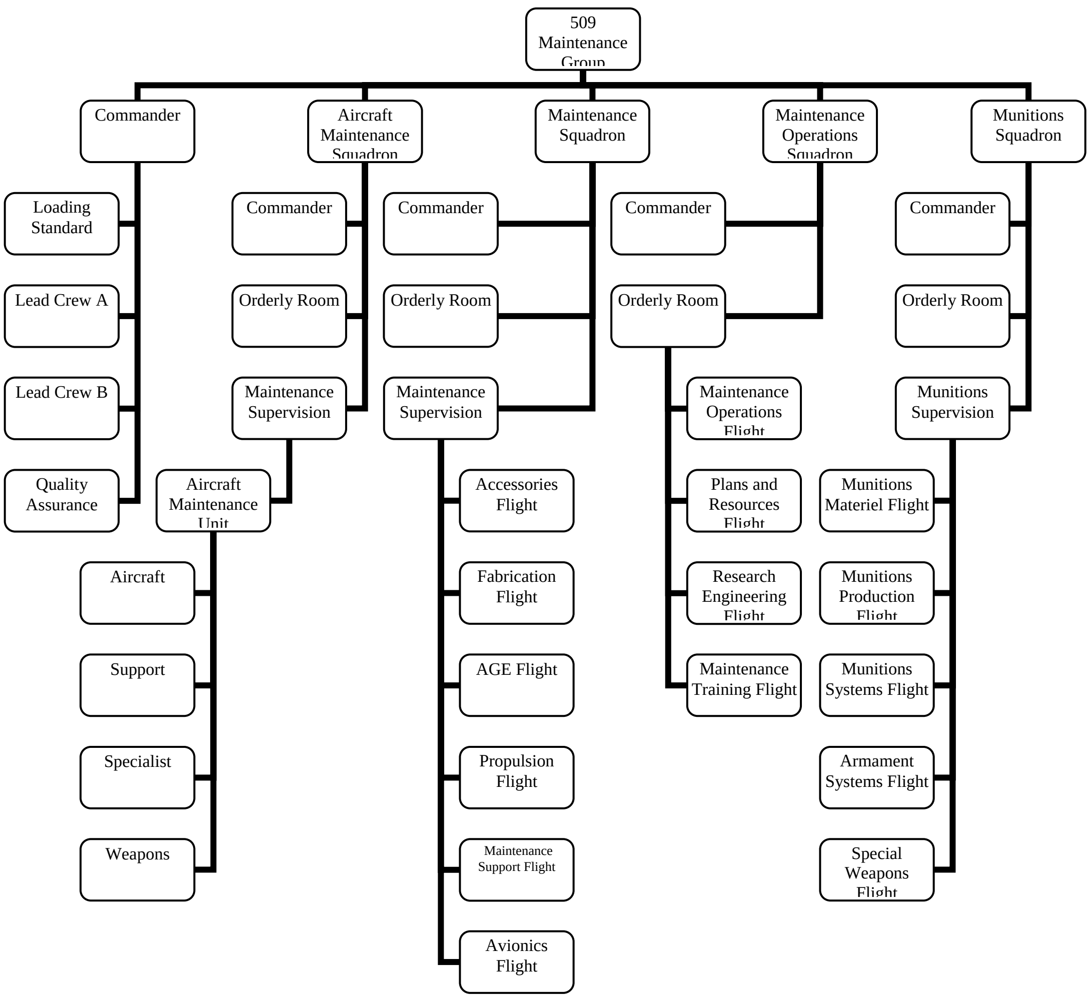

Figure 32. 509th B-2 Maintenance Group Organizational Structure
(Air Combat Command, 2006)

This organizational structure was also the framework for the RMLV MXG organization. Analysis of the LCOM study was conducted in two parts. First, the scenario and assumptions of the study were compared to RMLV mission requirements to determine similarities and differences. Second, the manpower determinations for each workcenter were reviewed to determine the applicability of the requirement to RMLV operations as reflected in MILEPOST.

Scenario and Assumptions.

The study addresses manpower requirements for both sustained wartime and peacetime operations (Air Combat Command, 2006: 2). Air Expeditionary Force (AEF) commitments were not modeled, so there were no manpower adjustments required to account for the non-expeditionary nature of the RMLV fleet. For both scenarios, the total Primary Aircraft Inventory (PAI) supported by the maintenance personnel was 16; however, in peacetime this PAI included both B-2s and T-38s while in wartime, the PAI consisted of an 8 PAI independent B-2 package and an 8 PAI dependent B-2 package (Air Combat Command, 2006: 6). The most stringent requirement out of these scenarios determined the actual manpower requirement (Air Combat Command, 2006: 5). Since the wartime scenario supporting 16 B-2s posed the most stringent requirement, there was no need to make adjustments to isolate the manpower requirements for the T-38 support provided under the peacetime scenario. As a result, the RMLV fleet size of 6 was compared to the B-2 supported fleet size of 16, and the 6/16 ratio became part of a parametric relationship and sensitivity analysis established later in the Parametric Relationships section of this chapter.

The peacetime scenario simulated three eight-hour shifts, five days per week, primarily in the production workcenters (Air Combat Command, 2006: 6). The wartime scenario modeled two 12-hour shifts, seven days per week in all workcenters, based on the sortie rates in the War Mobilization Plan (Air Combat Command ND, 2006: 6). According to AF policy, these scenarios drive certain factor calculations that are used to modify manpower requirements. The overload factor ensures that assets are utilized efficiently (Air Force, 2003: 14). The man-hour availability factor is the average number of man-hours per month that personnel are available for primary duty, accounting for time spent each month on training, mandatory appointments, and other military requirements (Air Force, 2003: 13). Additionally, LCOM assigned maximum direct workcenter utilization rates for both peacetime and wartime scenarios. These factor calculations were assumed to be similar for the RMLV fleet, as they are AF-approved modifications, with the result that the LCOM manpower calculations were assumed to be fundamentally consistent with future RMLV workcenters. However, an RMLV fleet that operates three eight-hour shifts, seven days a week does not align directly with either of these scenarios. As a result, a shift factor was used in a parametric relationship and sensitivity analysis in the Parametric Relationships section of this chapter.

Several assumptions factored into the LCOM calculation of daily flying and maintenance operations. Sorties were programmed randomly throughout each 24-hour period (Air Combat Command, 2006: 15). Maintenance workload data and planning factors were validated and verified during the LCOM planning stage (Air Combat Command D, 2006: 2). Failure rates are annotated in the model as Maintenance Action Rates which reflect the mean sorties between maintenance actions, and were determined by an earlier audit at Whiteman AFB (Air Combat Command, 2006: 2). Spare parts availability was addressed in the model using a Total Non-mission Capable Supply rate of 7%, based on historical data (Air Combat Command, 2006: 11). Additionally, the air abort rate was set at 2% within the model, based on historical data (Air Combat Command, 2006: 17). Depot repair was included in the model, based on the three-level maintenance concept, with a turnaround time of 13 days (Air Combat Command, 2006: 11). Without specific operational, maintenance, and supply data for the RMLV, these assumptions were accepted as sufficient to determine RMLV manpower requirements.

Facilities and equipment are not part of the scope of this thesis; however, their impact on manpower was taken into consideration in the LCOM model. LCOM modeled one engine test cell, located at Whiteman AFB, which was used for both peacetime and wartime workload (Air Combat Command 6: 11). All other facilities and equipment were modeled according to current configuration and authorizations, which included an assigned hangar for each aircraft (Air Combat Command: 11). As part of a study modeling projected resource utilization for varying numbers of annual RMLV launches, an approximate 1:1 ratio of fleet size to maintenance hangars was established as optimal to achieve required launch rates, and supports the assumption of individual vehicle hangars (Rooney, 2006: 8).

One factor of note for comparison to the RMLV is that the B-2 has an On-Board Test System (OBTS) which is supported by its own section, CIT/CEPS, under the Maintenance Group Orderly Room (Air Combat Command, 2006: 19). The CIT/CEPS section for the B-2 is a variance to the manpower standard to provide “24-hour, 7 days a week software analysis support” to process and analyze OBTS data (Air Combat

Command, 2006: 29). Assuming an IVHM system would be part of the RMLV design, a similar variance was applied.

Workcenter Requirements.

Table 11 summarizes, by squadron, the first step in the analysis that was performed to derive RMLV manpower requirements from the B-2 LCOM study results.

Table 11. RMLV Requirements Derived from 2005 B-2 LCOM Results

Workcenter	Areas of Responsibility	**LCOM Derived Total** (accounts for workcenter, variance, and overhead adjustments)
MXG Staff	Commander, Support, Quality Assurance, Load Team Training and Evaluation	40
MOS	Analysis, Maintenance Operations Center, On-Board Test System Analysis	84
MXS	Backshop Maintenance	501
MUNS	Weapons and Armament maintenance and support	164
AMXS	Flightline Maintenance and Weapons Loading	303
MXG Total		**1092**

Workcenters that did not apply to RMLV operations were removed. These workcenters, and the justifications for omitting them, are listed at Appendix B. Once these workcenters were removed, their respective overhead functions were adjusted proportionally. Additionally, positive manpower variances awarded to the B-2 for reasons that were not applicable to the RMLV were subtracted. Variance and overhead adjustments are recorded in Appendix C. Further adjustments required to account for a number of differences between the RMLV and B-2 were established and analyzed in the Parametric Relationships section of this chapter.

In summary, the 2005 B-2 LCOM analysis provided a starting point for establishing RMLV manning requirements. Of the 1,536 personnel projected to support the B-2s under the scenario and assumptions of the study, 1,092 of them manned workcenters that would also be required to support RMLV operations. A review of the LCOM study identified that adjustments would be required for the number of shifts and the fleet size; these and other adjustments were developed and applied in the Parametric Relationships section of this chapter. In the next section, the results of the LCOM analysis for the Predator were assessed to determine if an unmanned platform revealed any necessary adjustments to these workforce numbers.

UAV Comparison Data

To address any available insights provided by an unmanned platform, the 2005 LCOM report for the MQ-1 Predator was also reviewed and analyzed. Compared to the B-2, the Predator exhibited a smaller, simplified maintenance organizational structure, shown in Figure 33.

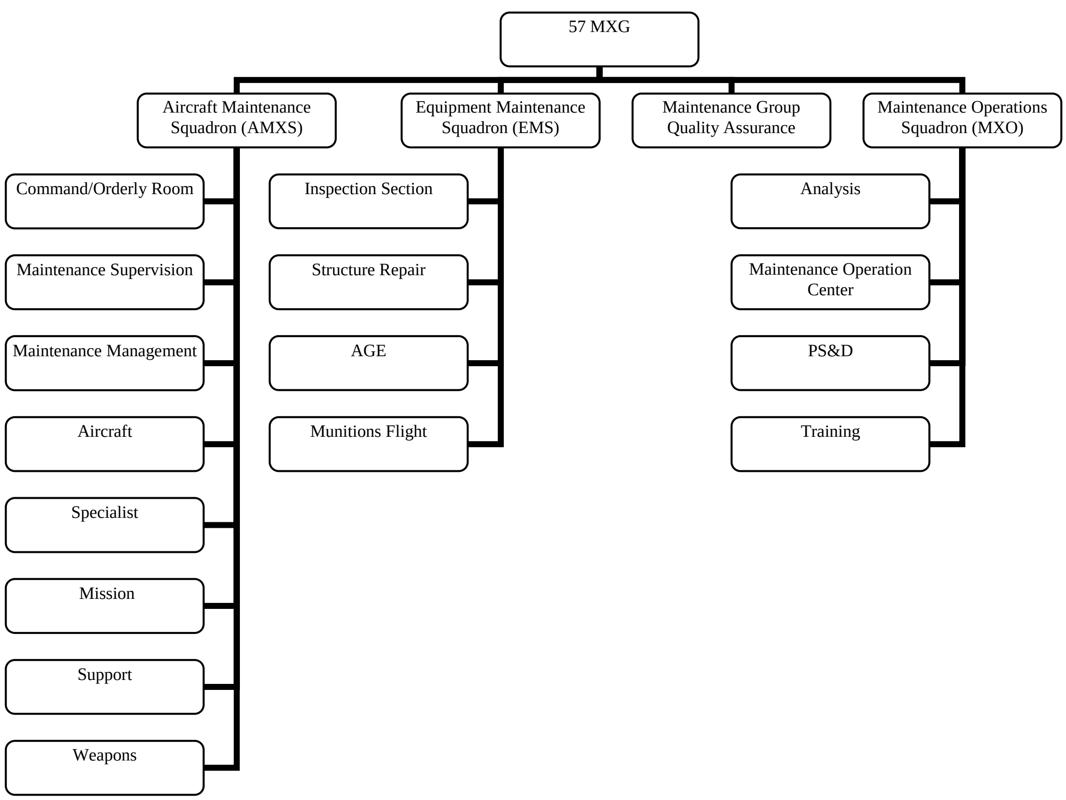

Figure 33. 57th MXG Predator Maintenance Group Organizational Structure

Scenario and Assumptions.

The study addressed manpower requirements for wartime operations (Air Combat Command, 2005: 6), engaging two 12-hour shifts, seven days a week (Air Combat Command, 2005: 12). As with the B-2, the modification factors driven by these operational conditions were assumed to apply accurately to the RMLV; however, adjustments would be required to account for eight-hour shifts. AEF commitments were modeled, in the form of a continuous deployment of one system, which required five teams of personnel to support 120-day rotations every 20 months (Air Combat Command, 2005: 9). This requirement was not applicable to the RMLV. The model assessed support for three Predator Systems, each composed of 4PAI, 1 Ground Control Station (GCS), and 1 Predator Primary Satellite Link (PPSL) (Air Combat Command, 2005: 6). This total of 12 aircraft supported, along with additional ground systems, was also greater than the expected size of the RMLV fleet.

Predator sorties were scheduled at random on a 24-hour, 7-day schedule (Air Combat Command, 2005: 11). The Predator executed two types of missions: 75% were Hunter-Killer sorties, for which the Predator was armed with Air-to-Ground Missiles, and 25% were Intelligence Surveillance Reconnaissance sorties, for which the Predator was armed with a Synthetic Aperture Radar (Air Combat Command, 2005: 12). While the B-2 organizational structure supported only maintenance and loading of weapons, the Predator's radar support was assessed for the ability to provide a more accurate assessment of RMLV payload operations.

Maintenance failure rates were determined based on Maintenance Data Collection data (Air Combat Command, 2005: 2), while "task times and crew sizes for both scheduled and unscheduled maintenance were collected, verified and validated during a field audit at Indian Springs in January 2004" (Air Combat Command, 2005: 2). Spare parts availability was addressed in the model using a Total Non-mission Capable Supply rate of 2.8%, based on historical data (Air Combat Command, 2005: 9). Depot/contractor repair was included in the model with a turnaround time of 17 days (Air Combat Command, 2005: 9). Additionally, LCOM modeled phase inspections at 100-hour intervals for the aircraft and 300-hour intervals for the engines (Air Combat Command, 2005: 9). Since the Predator System includes the GCS and PPSL, these equipment items were modeled as a constraint on Predator operation, and both scheduled and unscheduled maintenance for them was included in the Predator model (Air Combat Command, 2005: 11). The specialized transportation and handling equipment required by the RMLV would likely introduce a similar constraint to modeling RMLV operations.

Facilities and equipment are not part of the scope of this thesis; however, their impact on manpower was taken into consideration in the LCOM model. LCOM assumed full availability of maintenance facilities and support equipment (Air Combat Command, 2005: 9).

Finally, as the Predator squadron is supported by the 57th MXG at Nellis AFB, its manning requirements form additional authorizations within existing MXG workcenters supporting the Weapons School, Test, and Thunderbirds aircraft (Air Combat Command, 2005: 29). While the RMLV will likely operate out of Vandenberg or Cape Canaveral, with an established wing support structure, neither location has an existing MXG supporting other platforms.

Workcenter Requirements.

Table 12 provides a summary of the LCOM study results for the Predator. Again, workcenters that did not apply to RMLV operations were removed. These workcenters, and the justification for omitting them, are listed at Appendix B. The LCOM results were not further adjusted for variations or overhead, however, since the Predator was only being used as a comparison platform, and not as a baseline for determination of RMLV requirements. As an unmanned platform, the composition of the Predator's organizational structure had the potential to reveal significant differences from the B-2 structure that would alter the magnitude or proportional contribution of individual maintenance workcenters. The information in Table 12 was used to identify significant trends that might reflect the need to make adjustments to the manpower requirements identified in the previous section.

Table 12. Predator Maintenance Group Manning

Workcenter	Areas of Responsibility	**LCOM Derived Total** (accounts for workcenter adjustments)
MXG Staff	Quality Assurance	6
MXO	Analysis, Maintenance Operations Center, Planning, Scheduling, Documentation, Training	8
EMS	Backshop Maintenance, Weapons maintenance, support	66
AMXS	Flightline Maintenance and Weapons Loading	196
MXG Total		276

The Predator required a much smaller maintenance support unit than the B-2, with a composition that was much heavier on AMXS support, and much lighter on MXG, MXS, and MOS manpower requirements than its crewed counterpart. However, key differences beyond the unmanned nature of the vehicle drove the proportional dissimilarity. First, the Predator was supported by an existing MXG that also supported other airframes. As such, MXG, MXS, and MOS requirements were shared among airframes, while the on-aircraft nature of the AMXS mission required dedicated manpower for each platform. As established in Chapter VI, Analysis of Organizational Structure, the RMLV is likely to be supported by an MXG at Vandenberg or Cape Canaveral that will not support other reusable platforms; therefore, manpower savings will not be available through consolidating MXS, MXG, or MOS functions. Secondly, the expeditionary nature of the Predator contributed to its increased AMXS requirements compared to the RMLV. The Predator MXG organization was built to support five teams of personnel to meet AEF rotation requirements, resulting in an overall increase in requirements. The RMLV will not be expeditionary, and will not justify these personnel increases.

Initially, it seemed possible that maintenance support for installation of the Predator's radar payload would more accurately reflect RMLV payload operations than the B-2's weapons loading. However, since a majority of the Predator's missions require ordnance payloads as well, no significant difference was noted in the Predator weapons workcenter that would render it more applicable to RMLV payload support.

In summary, the sources of the differences in Predator manning compared to B-2 manning were not found to be applicable to RMLV operations. As such, no modifications were made to the manning requirements identified in the previous section. However, the idea of modeling GCS and PPSL as constraints on Predator availability will apply to future research modeling the effect of GSE on the RMLV in MILEPOST.

Parametric Relationships

In order to establish some useful parametric relationships to further refine the RMLV maintenance manpower estimates, this section focused on a series of adjustment factors, each developed based on research and then subjected to sensitivity analysis. First, a parametric factor addressing the number of shifts was developed and assessed. Second, the proportion of maintenance man-hours spent on individual maintenance functions for the Shuttle was compared to comparable B-2 workcenter contributions to allow the organizational structure to be adjusted to more accurately reflect the proportional sizes of workcenters for space vehicle maintenance. Third, a comparison of estimated surface area allowed direct adjustment to the Structural Repair workcenter, a critical component in both B-2 and RMLV maintenance. Fourth, the relative complexity of a space platform in comparison to the B-2 was derived from a comparison of total workforce sizes, allowing the overall workforce magnitude to be adjusted appropriately. Finally, the total workforce was adjusted for varying fleet sizes.

Number of Shifts.

Due to the stringent requirement for a 24-hour response and turnaround time for the RMLV, this research assumed a manning requirement for three shifts performing 24-hour operations seven days a week. In order to derive the third shift requirements from the B-2 LCOM study results, a shift factor of 1.5 was applied to each workcenter. Any fraction of a manpower position was rounded up. The results are shown in Table 13.

Table 13. Adjustments for Number of Shifts Factor

B-2 Workcenter	2 Shifts (LCOM Total)	3 Shifts (LCOM Total * 1.5)
MXG Staff	40	61
MOS	84	129
MXS	501	755
MUNS	164	249
AMXS	303	456
MXG Total	**1092**	**1650**

Adding a third shift required a personnel increase of approximately 550 personnel. At this stage in the manpower assessment, the possible design points listed in Table 14 have been established in accordance with the experimental design process outlined in Chapter IV, Methodology.

Table 14. Design Points for Number of Shifts Adjustmen

Design Point	Factor
	Shifts
1	2
2	3

Both two-shift and three-shift manning options were explored as part of sensitivity analysis for the parametric relationships to follow.

Space Vehicle Maintenance.

A second concern in assessing parametric relationships for the RMLV lies in the fact that the distribution of maintenance man-hours to the subsystems on an aircraft may not be the same as the distribution of maintenance man-hours to the subsystems on a space vehicle. For example, the specialized thermal protection structures on a space vehicle may result in a much greater percentage of total maintenance man-hours dedicated to structural maintenance that what is reflected in the B-2 organization. As a result, this factor compared the relative contribution of individual workcenters to total Shuttle maintenance with the relative contribution of individual workcenters to total B-2 maintenance in order to determine required mathematical adjustments.

An analysis of B-2 manning requirements as determined by the 2005 LCOM study resulted in the workcenter contribution ratios identified in Table 15, calculated by dividing the manpower requirement for the workcenter by the total MXG manpower. A full account of LCOM workcenter contributions is available at Appendix D.

Table 15. B-2 Percent of Total Manpower by Workcenter

Workcenter	Area of Responsibility	% Total Manpower
MXG	Commander, Support, Quality Assurance, Load Team Training, Evaluation	3.52%
MOS	Analysis, Maintenance Operations Center, On-Board Test System Analysis	5.60%
MXS	Backshop Maintenance	34.18%
MUNS	Weapons and Armament maintenance and support	17.25%
AMXS	Flightline Maintenance and Weapons Loading	39.45%

B-2 Maintenance is heavily focused on flightline operations, with backshop repairs forming the remainder of almost 75% of total maintenance requirements. This is consistent with an operation that demands rapid turnaround times and also requires heavy maintenance of specialized LO structural components during mission down-times. Only 25% of the entire maintenance workforce is devoted to payload operations (munitions), analysis, command and control, on-board test system monitoring, quality assurance, and all other support operations. The rest of this section was devoted to comparing these functional proportions with known ratios for Shuttle maintenance operations to assess similarities and differences. Two sources of information were utilized for Shuttle maintenance data: an RMLV modeling effort that compiled Shuttle maintenance data to develop failure and repair rate distributions, and a NASA publication that collected detailed Shuttle maintenance data to identify design root causes of long turnaround times.

<u>Shuttle Maintenance Analysis for RMLV Modeling.</u>

In developing a discrete-event simulation of turnaround time and manpower requirements for military reusable launch vehicles, AF Aeronautical Systems Center (ASC) personnel compiled historical Shuttle maintenance data from STS-85 by functional area in order to develop probability distributions for RMLV component failures and maintenance actions, shown in Figure 34 (Rooney, 2005: 2). This data is summarized in Table 16 and is compared to B-2 workcenter percentages to compare the contributions of specific maintenance actions to overall support requirements.

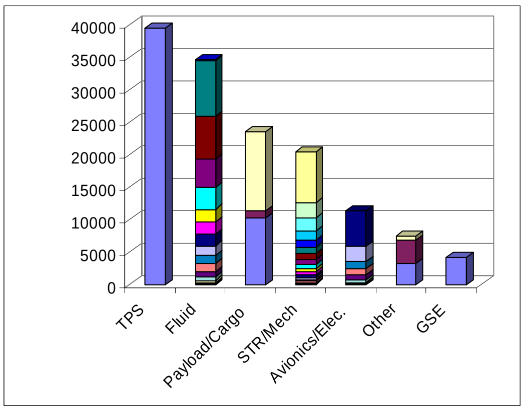

Figure 34. Shuttle Mx Data by Activity (Rooney, 2005: 2)

Table 16. Shuttle % of Man-hours by Activity

Mx Activity	Man-hours	Percent of Total
TPS	39000	28.47%
Fluids	34000	24.82%
Payload/Cargo	23000	16.79%
STR/Mech	20000	14.60%
Avionics/Electric	11000	8.03%
Other	6000	4.38%
GSE	4000	2.92%

To provide the most accurate comparison, specific B-2 workcenters corresponding to the identified RMLV maintenance activities are listed in Table 17.

Table 17. B-2 Workcenters for Comparison

Workcenter	Area of Responsibility	% Total Manpower
MXS	Structural Repair Section (highest single contributor)	11.91%
MXS	Electrics/Environmental Section	0.78%
MXS	Propulsion Flight	2.80%
AMXS	Weapons Loading Section	4.88%
MXS	Avionics Flight	2.34%
MXS	Aerospace Ground Equipment (AGE) Flight	6.45%

Unfortunately, there is not a direct correlation between each maintenance activity identified in the ASC research and an aircraft maintenance workcenter supporting the B-2. For instance, the Structural Repair workcenter would perform both TPS and

STR/Mech activities. Shuttle Fluids maintenance, which includes "main engine pressurization and feed system, Orbital Maneuvering System and Reaction Control Systems (OMS/RCS), the Auxiliary Power Units (APU), actuation system, and Active Thermal Control System (ATCS)" (Rooney, 2005: 7), would be performed by the Electrics/Environmental section and Propulsion Flight workcenters. Finally, Payload/Cargo functions are most closely approximated by the Munitions Squadron and the Weapons Loading section. A detailed assessment of Shuttle maintenance disciplines and their aircraft maintenance counterparts, derived from LCOM and AF personnel guidance, is provided at Appendix E.

The proportional Shuttle man-hour requirements, as summarized for projected RMLV maintenance, exhibited similar proportional characteristics to B-2 maintenance; however, there were some striking differences. Table 18 summarizes the comparison data, listing each Shuttle activity with its corresponding B-2 workcenters, and comparing the two to demonstrate the magnitude of differences.

Table 18. Comparison of Shuttle and B-2 Maintenance Drivers

Shuttle Mx Activity	B-2 Workcenter	Ratio	Difference*
TPS/Fluids/STR/Mech/ Avionics/Electric/ GSE	AMXS/MXS	78.84%: 73.63%	**5.21% (S)**
Fluids/Avionics/ Electric	MXS Electrics/Environmental/ MXS Propulsion/MXS Avionics	32.85%: 5.92%	**26.93% (S)**
Payload/Cargo	MUNS/AMXS Weapons	16.79%: 22.13%	**5.34% (B)**
TPS/STR/Mech	MXS Structural Repair	43.07%: 11.91%	**31.16% (S)**
Avionics/Electric	MXS Electrics/Environmental/ MXS Avionics	8.03%: 3.12%	**4.91% (S)**
GSE	MXS AGE	2.92%: 6.45%	**4.16% (B)**
*(S) indicates the Shuttle experiences a larger impact from the function; (B) indicates the B-2 experiences a larger impact from the function			

First, an overall assessment of all AMXS- and MXS-aligned Shuttle functions (TPS, Fluids, Structures/Mechanics, Avionics/Electrics, and GSE) revealed that the proportion was fairly similar, at approximately 75% of total maintenance requirements. Payload/Cargo operations and Shuttle GSE maintenance were within 5% of their B-2 counterparts.

An analysis of Fluid operations required combining the total with the Avionics/Electric activity because the Electronics/Environmental aircraft section and Propulsion Flight combine to perform the function of the Shuttle Fluid workcenter. This, in turn, led to adding the B-2 Avionics Flight percentage to the aircraft proportion for a comparable workcenter total. The result showed an impact from Fluids/Avionics/Electric operations on the Shuttle that was 27% greater than the parallel functions performed for the B-2. By isolating the Avionics/Electric component and comparing it against the Avionics and Electrics/Environmental section of B-2 maintenance, it seemed that the greatest portion of this disparity was due to increased Shuttle requirements specific to fluids, rather than electrics or avionics. This comparison will be examined in further detail in the next section, Shuttle Maintenance Analysis for Design Root Cause.

As noted in Tables 16 and 17, TPS maintenance was the most significant contributor to Shuttle maintenance man-hours, while Structural Repair was the most significant single contributor to B-2 manpower requirements. However, at almost 45% of total man-hours, the TPS/Structures contribution to Shuttle maintenance is 31% higher than the Structural Repair contribution to B-2 maintenance. In order to observe the effect of Shuttle-like TPS on the B-2-based manpower structure, the following calculations were performed on the Table 13 manpower numbers to adjust the Structural Repair workcenter to reflect a 31% greater contribution to total maintenance man-hours:

a. Workcenter calculations: 1. The two-shift workcenter numbers resulted in a total of 184/1,092 personnel in the Structural Repair workcenter, accounting for 16.85% of the total. A 31% increase in this percentage resulted in a new manning level of 523 personnel. 2. The three-shift workcenter numbers resulted in a total of 276/1,650 personnel for these two workcenters, accounting for 16.73% of total manpower. A 31% increase resulted in a new manning level of 788 personnel.

b. Overhead calculations: 1. For two-shift operations, 339 additional personnel yielded a 70% increase over the previous MXS functional manning (MXS total – MXS/CC/CQ/MXM) of 486 personnel, which was distributed to the two MXS overhead sections. The resulting 33% increase in the four-squadron total (350 additional personnel compared to 1,052) was applied to the MXG/CC workcenter. 2. For three-shift operations, 512 additional personnel compared to 732 previously assigned to functional workcenters also yielded a 70% increase, distributed to the two MXS overhead workcenters. The resulting 33% increase in the MOS/AMXS/ MXS/MUNS total (529 additional personnel compared to 1,589) was applied to the MXG/CC workcenter.

c. After addressing both two- and three-shift options, the resulting manpower requirements are displayed in Table 19. Bold and italicized numbers indicate values that changed as a result of the application of this parametric adjustment.

Table 19. Adjustments for TPS Factor

Workcenter	**2 Shifts TPS Factor 1.31**	**3 Shifts TPS Factor 1.31**
MXG Staff	***42***	***64***
MOS	84	129
MXS	***851***	***1284***
MUNS	164	249
AMXS	303	456
MXG Total	***1444***	***2182***

These totals showed a significant increase over the previous estimates of 1,092 personnel for two shifts or 1,650 personnel for three shifts. The magnitude of the manpower increase experienced by maintaining a Shuttle-like TPS system presents a strong argument for design alternatives that reduce thermal protection requirements. Additionally, the Structural Repair workcenter in the B-2 MXG baseline is already considerably larger than those in other maintenance organizations due to the LO support requirements. In maintenance organizations supporting aircraft like the B-1, B-52, and F-15E, where the Structural Repair workcenter accounts for less than 5% of total maintenance manpower (Air Combat Command, B-1, 2003: 104; Air Combat Command, B-52, 2003: 5-5; Air Combat Command, F-15E, 2003: 5-3); only the F-117 proportion, at 9% approaches that of the B-2, again due to maintenance requirements for the stealth technology (Air Combat Command, F-117, 2001: 5-2). As a result, minimizing or eliminating TPS requirements could result in a much smaller workcenter than indicated by the B-2 baseline. Because research indicates that the RMLV will use reduced amounts of thermal protective material that are more durable and easier to repair and replace (Rooney, 2006: 4), these adjustments were not incorporated into further manpower calculations. As a stand-alone calculation, the TPS factor was not entered into the design points structure.

The next section will explore additional Shuttle maintenance data to further isolate significant workcenter differences.

Shuttle Maintenance Analysis for Design Root Cause

In order to more closely pinpoint these differences, the next comparison used more detailed Shuttle maintenance activity information, gathered for a NASA technical publication addressing the design root causes for extended Shuttle turnaround times (McCleskey, 2005: iii). This data, shown in Table 20, was collected across eight STS processing flows in 1997, and categorized by maintenance function in order to determine the Shuttle design characteristics that posed the greatest maintenance impact during turnaround operations (McCleskey, 2005: 19).

Table 20. Shuttle Percent of Man-hours by Activity (McCleskey, 2005: 19, 243-244)

Workcenter	Area of Responsibility	% Total Man-hours
Structures, Mechanisms, & Vehicle Handling	Orbiter Systems Observer, Quality Engineering, Orbiter Handling Equipment, Ground-Support Equipment (non-specific), Optical Systems, Mechanical Systems, Orbiter Structures, Pyrotechnic Systems	33.69%
Liquid Propulsion	Shuttle Main Engines Engineering, Main Propulsion Systems, OMS-RCS	15.70%
Thermal Management	Freon and Water Cooling Loops, Tile, and Blankets	11.69%
Power Management	Orbiter Test Conductor, APU, Electrical Power Distribution, Orbiter Electrical, Fuel Cell Systems, Hydraulic Systems	10.05%
Safety Management & Control	Purge, Vent & Drain Systems, Main Propulsion Systems, Main Engine Safety Purges	8.31%
Ground Interfacing Systems & Facilities	Ground Support Equipment (non-specific)	7.26%
Payload Accomodations	Payload Installation/Removal Operations	4.08%
Environmental Control & Life Support	Orbiter Cooling and Life Support	3.65%
Command, Control, & Health Management	Orbiter Data Processing System, Orbiter Instrumentation Systems, Software	3.44%
Communications	Orbiter Communications Systems	0.87%
Guidance Navigation & Control	Guidance, Navigation, and Control Systems	0.62%

Again, no direct correlations to aircraft maintenance workcenters were available, due to the significant overlap of functions within individual Shuttle workcenters. However, some proportional relationships were still derived related to groups of aircraft maintenance workcenters. The B-2 workcenters listed in Table 21 were used for comparison to this data set, chosen as indicated by the assessment of Shuttle maintenance disciplines and their aircraft maintenance counterparts at Appendix E.

Table 21. B-2 Workcenters for Comparison

Workcenter	Area of Responsibility	% Total Manpower
AMXS	Weapons Loading Section	4.88%
MOS	CIT/CEPS	0.72%
MOS	Maintenance Operations Center Section	1.17%
MOS	Research Engineer Section	0.65%
MXG	Quality Assurance Section	2.02%
MXS	Electrics/Environmental	0.78%
MXS	Avionics Flight	2.34%
MXS	Fuels Section	1.30%
MXS	Propulsion Flight	2.80%
MXS	Pneudraulics Section	.59%
MXS	Metals Technology Section	0.59%
MXS	Structural Repair Section	11.91%
MXS	Survival Equipment Section	0.46%
MXS	Aerospace Ground Equipment (AGE) Flight	6.45%

The Structures, Mechanisms, and Vehicle Handling Shuttle activity was the most comprehensive of the workcenters, encompassing a wide range of MXS, AMXS, and MOS functions, including AGE. As a result, it was combined with Ground Interfacing Systems & Facilities, primarily responsible for GSE, to establish an accurate total ratio. Additionally, Command, Control & Health Management, Communications, and Guidance, Navigation & Control were all combined due to their reliance on the Electrics/Environmental and Avionics aircraft maintenance workcenters.

Table 22 summarizes the comparisons between this set of Shuttle maintenance activities and corresponding B-2 maintenance workcenters.

Table 22. Comparison of Shuttle and B-2 Maintenance Drivers

Shuttle Mx Activity	B-2 Workcenter	Ratio	Difference*
Structures, Mechanisms, & Vehicle Handling/ Ground Interfacing Systems & Facilities	AMXS Weapons Loading/ MOS MOC/MXG QA/MXS AGE/MXS Avionics/MXS Metals Technology/MXS Structural Repair/MXS Survival Equipment	40.95%: 29.82%	11.13% (S)
Liquid Propulsion	MOS Research Engineer/ MXS Propulsion	15.70%: 3.45%	12.25% (S)
Thermal Management	MXS Electrics/Environmental /MXS Structural Repair	11.69%: 12.69%	1.00% (B)
Power Management	MOS CIT/CEPS/ MXS Electrics/ Environmental/ MXS Fuels/MXS Pneudraulics	10.05%: 3.39%	6.66% (S)
Safety Management & Control	No specific workcenter identified. AF aircraft maintenance policy holds each individual and workcenter responsible for proper safety training, awareness, and procedures (Air Force, 2006: 44).		
Ground Interfacing Systems & Facilities	MXS/AGE	7.26%: 6.45%	0.81% (S)
Payload Accomodations	AMXS Weapons	4.08%: 4.88%	0.80% (B)
Environmental Control & Life Support	MXS Electrics/Environmental	3.65%: 0.78%	2.87% (S)
Command, Control & Health Management/ Communications/ Guidance, Navigation & Control	MOS CIT/CEPS/MXS Electrics/Environmental/ MXS Avionics	4.93%: 3.84%	1.09% (S)
*(S) indicates the Shuttle experiences a larger impact from the function; (B) indicates the B-2 experiences a larger impact from the function			

Unfortunately, this data set was more challenging to analyze for individual B-2 workcenters, since most Shuttle functions required multiple workcenter skills, and many workcenters appeared across multiple functions.

However, one comparison was clear, and supported the finding in the RMLV modeling dataset. Liquid Propulsion, a similar Shuttle maintenance requirement to the Fluids function analyzed above, applied directly to MXS Research Engineer and Propulsion Flight and demonstrated a 12% greater impact on maintenance man-hours for the Shuttle than for the B-2. Because this dataset allowed for more specific isolation of the appropriate B-2 workcenter, the MXS Propulsion Flight and MOS Research Engineer were increased to contribute 12% more to total RMLV manpower requirements, and overhead functions were adjusted accordingly.

The only other major disparity was in the arena of Structures, Mechanisms, and Vehicle Handling. However, this Shuttle function incorporated too many aircraft workcenters to determine a specific parametric relationship. It was clear that an adjustment factor would be required for the Structural Repair workcenter, but this factor will be determined through an estimated size comparison in the Surface Area section.

To summarize, a comparison of the relative contributions of individual Shuttle maintenance activities to overall man-hour requirements revealed a general similarity to the contribution of individual B-2 maintenance workcenters to overall manpower requirements. However, significant dissimilarities were noted. First, manpower implications of a Shuttle-like thermal protection system were assessed, yielding results that strongly supported minimizing TPS requirements. Second, a disparity in percent contribution was noted in Shuttle Liquid Propulsion, corresponding to the B-2 MXS Propulsion Flight and MOS Research Engineer workcenters. An adjustment factor of 12% was used to increase the size of the Propulsion Flight, according to the following calculations, which are presented in detail by workcenter in Appendix F:

a. Workcenter calculations: 1. The two-shift workcenter numbers result in a total of 53/1,092 personnel for these two workcenters, accounting for 4.85% of total manpower. The adjustment will require these workcenters to account for 16.85% of 1,092 personnel, which amounts to 185 total personnel. The 132 additional personnel were divided among the workcenters using the formula: 132*(workcenter personnel/53). 107 personnel were assigned to Propulsion Flight, and 25 were assigned to the Research Engineer. 2. The three-shift workcenter numbers result in a total of 80/1650 personnel for these two workcenters, accounting for 4.85% of total manpower. The adjustment will require these workcenters to account for 16.85% of 1,650 personnel, which amounts to 279 total personnel. The 199 additional personnel were divided among the workcenters using the formula: 199*(workcenter personnel/80). 162 personnel were assigned to Propulsion Flight, and 37 additional personnel were assigned to the Research Engineer.

b. Overhead calculations: 1. For two-shift operations, in Propulsion Flight, 107 additional personnel compared to 486 personnel previously assigned to functional workcenters (MXS total – MXS/CC/CQ/MXM) yielded a 22% increase, which was distributed to the overhead workcenters. For the Research Engineer, 25 additional personnel accounted for a 32% increase over 79 functional workcenter personnel (MOS Total – MOS/CC/CQ), which was applied directly to the MOS/CC/CQ workcenter. The resulting total yielded a 13% increase for the MOS/AMXS/MXS/MUNS total (138 additional personnel compared to the previous four-squadron total of 1,052), which was applied to the MXG/CC workcenter. 2. For three-shift operations, in Propulsion Flight, 162 additional personnel compared to 732 personnel previously assigned to functional workcenters (MXS total – MXS/CC/CQ/MXM) yielded a 22% increase, which was distributed to the overhead workcenters. For the Research Engineer, 37 additional personnel accounted for a 31% increase over 121 functional workcenter personnel (MOS Total – MOS/CC/CQ), which was applied directly to the MOS/CC/CQ workcenter. The resulting total yielded a 13% increase for the MOS/AMXS/MXS/MUNS total (208 additional personnel compared to the previous four-squadron total of 1,589), which was applied to the MXG/CC workcenter.

c. After applying sensitivity analysis to account for two- and three-shift options, the resulting manpower requirements are displayed in Table 23.

Table 23. Adjustments for Propulsion Factor

Workcenter	2 Shifts, Propulsion Factor 1.12	3 Shifts, Propulsion Factor 1.12
MXG Staff	***41***	***63***
MOS	***111***	***169***
MXS	***612***	***923***
MUNS	164	249
AMXS	303	456
MXG Total	***1231***	***1860***

Bold and italicized numbers indicate those values that changed as a result of this parametric adjustment being applied to the appropriate workcenters. The net result was an increase of 139 personnel over two shifts or 210 personnel over three shifts.

At this stage in the manpower assessment, the possible design points listed in Table 24 have been established in accordance with the experimental design process outlined in Chapter IV, Methodology.

Table 24. Design Points for Propulsion Adjustment

Design Point	Factor
	Propulsion
1	2
2	3

Because the Propulsion Factor does not have a range of values, design points are the same as those established by the Shift Factor, and the results of this adjustment were combined under the heading of Shift Factor for remaining calculations

These numbers provided the basis for required adjustments due to differences in Surface Area, a relationship that will be explored in the next section.

Surface Area.

This parametric relationship accounted for the difference in size between the RMLV and the B-2, which directly affected the manpower requirements for the Structural Repair function, a significant contributor to total maintenance manpower requirements. Unfortunately, since the RMLV is still in the design phase, its exact size is not yet specified. Additionally, vehicle measurements were provided in length, height, and wingspan; however, surface area was a more accurate factor for Structural Repair manning, since the structures under maintenance are three-dimensional. As a result, vehicle surface area was approximated from dimensional information for the B-2 and Shuttle orbiter, roughly calculated based on the geometry of each platform, depicted in Figure 35.

Figure 35. B-2 and Orbiter Discovery (B-2 Spirit, 2007; STS-116, 2007)

The B-2 is essentially triangular in shape, and the surface area was estimated as the sum of the areas of two triangles, approximating the upper and lower surfaces. The orbiter main body was roughly calculated by summing two triangles, determined by the upper and lower wing surfaces, with three rectangular planes described by the orbiter length and height. Additionally, it was assumed that the RMLV will be smaller than the orbiter, so the resulting factor was rounded down. Surface area calculations are summarized in Table 25.

Table 25. Comparison of B-2 and Orbiter Surface Area

Dimensions	**Platform**	
	B-2	**Orbiter-Endeavor**
Length (Nose-to-Tail)	69 ft	122.17 ft
Wingspan	172 ft	78.06 ft
Height	17 ft	56.67 ft (diameter)
Surface Area Calculation	2 (1/2) (Wingspan) (Length)	2 (1/2) (Wingspan) (Length) + 3 (Height) (Length)
Estimated Surface Area	11868 sq ft	30307 sq ft

Based on these rough calculations, the orbiter surface area was approximately 2.6 times greater than the surface area of the B-2. As a result, the B-2 Structural Repair section was doubled, and overhead support was adjusted accordingly.

While the Shuttle Orbiter provided the only operational reusable comparison platform for surface area, other reusable launch vehicles have reached a design stage that allowed for further surface area comparison. Specifically, the Kistler K-1 fully reusable two-stage-to-launch vehicle was considered “the farthest along and the most technically feasible of the privately-funded commercial launch vehicle projects of the late 1990’s”

(Kistler K-1, 2007). Although the program has stalled out, the development team had solidified the preliminary design and had begun development and testing. The first stage, depicted in Figure 36, was cylindrical in shape, 60.2 feet long, and 22 feet in diameter.

Figure 36. Kistler K-1 Conceptual Design (Kistler K-1—Summary, 2007)

This equated to an estimated surface area of 4,200 square feet, approximately 35% of the estimated surface area of the B-2. The RMLV, as currently envisioned, will be a vertical take-off, horizontal landing platform that will require aerodynamic features such as wings and tail stabilizers. As such, it was not likely to be as small as the K-1 first stage, and the lower bound factor for the sensitivity analysis was rounded up slightly to 0.5.

While a Surface Area Factor of 2 was the primary assumption of this research for remaining workforce calculations, a sensitivity analysis was conducted to account for Surface Area Factors of 0.5, 2, and 2.5. The following calculations were applied to the Structural Repair workcenter to address differences in vehicle surface area:

a. Workcenter calculations: Both two- and three-shift workcenter numbers for Structural Repair were increased by factors of 0.5, 2, and 2.5.

b. Overhead calculations: 1. For two-shift operations, a factor of 0.5 resulted in a 16% decrease in the MXS (92 fewer personnel compared to 593 functional workcenter personnel); a factor of 2 yielded a 31% increase (184 additional personnel compared to 593); and a factor of 2.5 yielded a 47% increase (276 additional personnel compared to 593); these adjustments were applied to MXS overhead workcenters. The resulting changes of -8%, +16%, and +24% in the four-squadron totals (-96, +191, and +286 personnel compared to 1,190) were applied to the MXG overhead workcenter.

c. The resulting manpower requirements are shown in Table 26.

Table 26. Adjustments for Surface Area Factor

Workcenter	**Propulsion Factor 1.12**	**Surface Area = .5**	**Surface Area = 2**	**Surface Area = 2.5**
	2 Shifts			
MXG Staff	41	***40***	***43***	***43***
MOS	111	111	111	111
MXS	612	***516***	***803***	***898***
MUNS	164	164	164	164
AMXS	303	303	303	303
MXG Total	1231	***1134***	***1424***	***1519***
	3 Shifts			
MXG Staff	63	***62***	***65***	***66***
MOS	169	169	169	169
MXS	923	***779***	***1209***	***1351***
MUNS	249	249	249	249
AMXS	456	456	456	456
MXG Total	1860	***1715***	***2148***	***2291***

At this stage in the manpower assessment, the possible design points listed in Table 27 have been established in accordance with the experimental design process outlined in Chapter IV, Methodology.

Table 27. Design Points for Surface Area Adjustment

Design Point	**Factors**	
	Shift	**Surface Area**
1	2	0.5
2	2	2.0
3	2	2.5
4	3	0.5
5	3	2.0
6	3	2.5

Further manpower calculations continued to assess both two- and three-shift options, but utilized the central value of 2 as the best assessment for the Surface Area Factor.

Relative Complexity.

One of the most challenging differences to capture between B-2 and RMLV manning requirements was the greater vehicle complexity associated with a spacecraft. In order to establish a parametric relationship to approximate the net impact of this factor, it would be ideal to compare the total number of personnel performing ground support operations between subsequent Shuttle launches to the total number of personnel required for a B-2 turnaround. However, this information was not available from the United Space Alliance (USA) due to proprietary concerns. In its place, two estimations were performed. First, the approximate total number of USA employees was compared to the B-2 Bomb Wing, which had a similar scope of responsibilities. Second, the size of the Shuttle launch crew was used to estimate a total workforce requirement for comparison.

United Space Alliance employs approximately 10,000 personnel (USA Quick Facts, 2007) responsible for Shuttle processing, maintenance, and operations to include: mission planning, logistics and supply chain operations, software engineering, ground system design engineering, launch and recovery operations, mission control, training, flight crew equipment preparation and maintenance, and integration (Capabilities, 2007). Similarly, the 509th Bomb Wing employs approximately 3,900 personnel (509th Mission Support Squadron, 2007), and is primarily responsible for all operations and maintenance activities supporting the B-2 (Whiteman AFB Mission, 2007). In addition to orbiter support and maintenance, USA is also heavily engaged in support for the International Space Station, Extra Vehicular Activity Systems, and Ares I Crew Launch Vehicle Stage

1 studies (About USA, 2007). The 509th Bomb Wing supports an AF Reserve A-10 unit, an Army National Guard Apache helicopter unit, and a variety of base operation and personnel support functions in addition to its primary mission (Whiteman AFB, Missouri, 2007). In general, USA and the 509th Bomb Wing each perform similar functions supporting a primary platform, with a scope of duties that broadens considerably beyond the primary mission. This rough comparison resulted in the estimate that total Space Shuttle support requires approximately 2.5 times as many personnel as total B-2 support.

A more detailed comparison began with the Space Shuttle launch team, and extrapolated total workforce numbers based on the following relationship: Shuttle Launch operations accounted for 16.26% of total maintenance man-hours for eight launches in 1997 (McCleskey, 2005: 32). The Space Shuttle launch team is "a highly organized and disciplined group of approximately 500 professionals" (The Space Shuttle Launch Team, 2007), implying a total workforce size of approximately 3,075 personnel. The 2005 LCOM study estimated 1,536 personnel required to sustain B-2 operations under the modeled conditions. As a result, it was estimated that Shuttle maintenance support would require approximately two times as many personnel as B-2 maintenance support.

Again, due to the imprecise nature of these estimates, the manpower estimates accounting for vehicle complexity were performed at factors of 1.5, 2, and 2.5. A lower complexity factor, such as 1.5, may result from the fact that the Shuttle was hampered by both advancing age and crew considerations, neither of which will apply to the RMLV. The following calculations were performed to assess Vehicle Complexity:

a. Workcenter and Overhead calculations. For both two- and three-shift alternatives, using the manpower values derived at Surface Area Factor 2, each workcenter was adjusted using the formula: Complexity Factor*(workcenter personnel). All fractions of a manpower authorization were rounded up.

b. The resulting manpower requirements are summarized in Table 28.

Table 28. Adjustments for Complexity Factor

Workcenter	Surface Area = 2	Complexity = 1.5	Complexity = 2	Complexity = 2.5
	2 Shifts			
MXG Staff	43	***66***	***86***	***109***
MOS	111	***170***	***222***	***281***
MXS	803	***1209***	***1607***	***2011***
MUNS	164	***249***	***328***	***413***
AMXS	303	***456***	***606***	***759***
MXG Total	1424	***2150***	***2849***	***3573***
	3 Shifts			
MXG Staff	65	***99***	***130***	***164***
MOS	169	***257***	***339***	***426***
MXS	1209	***1817***	***2419***	***3025***
MUNS	249	***377***	***498***	***626***
AMXS	456	***686***	***912***	***1142***
MXG Total	2148	***3236***	***4298***	***5383***

The Complexity Factor established a wide range of manpower values, spanning more than 2,000 personnel between its lowest and highest settings. As such, reductions in vehicle complexity have the potential to yield significant manpower savings. The high magnitude of manpower requirements was mitigated in the next section, which addressed the RMLV's smaller fleet size.

At this stage in the manpower assessment, the possible design points listed in Table 29 have been established in accordance with the experimental design process outlined in Chapter IV, Methodology. While the Shift Factor continued to be assessed at two values, the Surface Area Factor was only assessed at its central value.

Table 29. Design Points for Complexity Adjustment

Design Point	Factors		
	Shift	Surface Area	Complexity
1	2	2	1.5
2	2	2	2.0
3	2	2	2.5
4	3	2	1.5
5	3	2	2.0
6	3	2	2.5

Remaining workforce calculations continue to address two- and three-shift alternatives, but assume the central Complexity Factor of 2, determined as the best estimate of this factor based on the research in this section.

Fleet Size.

The RMLV fleet size was assumed for the purposes of this research to consist of six boosters established as a requirement in the PRDA. However, fleet size has been identified in previous research as a parametric variable whose optimal value varies based upon annual launch requirements, and fleet sizes varying from one to seven vehicles were assessed in resource evaluations (Rooney, 2006: 7). As a result, this research conducted an assessment of manpower requirements for both two- and three-shift operations for fleet sizes ranging from one to seven vehicles using the following calculations:

a. Workcenter and Overhead calculations. For both two- and three-shift options, each workcenter was adjusted using the formula: Fleet Size Factor*(workcenter personnel). Fleet Size Factors were determined using the ratio of the number of RMLVs (one to seven) to the number of B-2s supported in the LCOM manpower assessment (16). All fractions of a manpower authorization were rounded up.

b. The resulting manpower requirements are summarized in Table 30.

Table 30. Adjustments for Fleet Size Factor

Workcenter	Complexity = 2	Fleet Size = 1/16	Fleet Size = 2/16	Fleet Size = 3/16	Fleet Size = 4/16	Fleet Size = 5/16	Fleet Size = 6/16	Fleet Size = 7/16
	2 Shifts							
MXG Staff	86	***7***	***12***	***18***	***23***	***28***	***34***	***39***
MOS	222	***19***	***32***	***46***	***59***	***75***	***88***	***102***
MXS	1607	***111***	***207***	***310***	***405***	***512***	***607***	***711***
MUNS	328	***30***	***47***	***69***	***85***	***110***	***128***	***149***
AMXS	606	***41***	***78***	***117***	***153***	***192***	***230***	***268***
MXG Total	2849	***208***	***376***	***560***	***725***	***917***	***1087***	***1269***
	3 Shifts							
MXG Staff	130	***10***	***18***	***26***	***34***	***42***	***50***	***58***
MOS	339	***26***	***46***	***69***	***88***	***109***	***132***	***152***
MXS	2419	***160***	***309***	***463***	***608***	***765***	***916***	***1068***
MUNS	498	***40***	***69***	***100***	***128***	***163***	***194***	***223***
AMXS	912	***60***	***117***	***174***	***230***	***288***	***344***	***402***
MXG Total	4298	***296***	***559***	***832***	***1088***	***1367***	***1636***	***1903***

These results demonstrated that the reduced RMLV fleet size considerably reduced the manpower requirements calculated in this research. Varying fleet size also yielded a wide range of workforce sizes, as manning requirements were highly dependent on the number of platforms supported. For a six-vehicle fleet performing 24-hour operations, the total MXG value assessed in this chart was 1,636 personnel. The Additional Sensitivity Analysis section of this chapter was used to shed further light on the range of RMLV manpower support requirements within the MXG.

At this point, based on the best-estimate determinations of research data for each factor value, the design points in Table 31 have been sampled according to the experiment design outlined in Chapter IV, Methodology.

Table 31. Sampled Design Points

Design Point	Factors			
	Shifts*	Surface Area	Complexity	Fleet Size
1	2	2	2	1
2	2	2	2	2
3	2	2	2	3
4	2	2	2	4
5	2	2	2	5
6	2	2	2	6
7	2	2	2	7
8	3	2	2	1
9	3	2	2	2
10	3	2	2	3
11	3	2	2	4
12	3	2	2	5
13	3	2	2	6
14	3	2	2	7

Design Point 13, representing three-shift operations of a six-ship fleet of RMLVs with Surface Area and Complexity Factors two times greater than the B-2, was the baseline manpower estimate of the MXG workforce size, totaling 1,636 personnel. While the selection of these design points was supported by factor-level selections based upon step-by-step research following the manpower assessment process, the combination of factors and levels encompassed a much wider range of design points than have been captured up to this point. The complete set of design points is included at Appendix I. In the Additional Sensitivity Analysis section, a random sampling of design points was conducted to address sample points not specifically covered by the research progression. First, a final stand-alone calculation assessed the impact of Integrated Vehicle Health Management (IVHM) Technology on the baseline manpower estimate.

IVHM.

The utilization of an Integrated Vehicle Health Management system, developed and coordinated into the early stages of the design process, has the potential to greatly reduce RMLV maintenance manpower requirements. The C-17, for instance, utilizes an automated system that collects "engine health data, built-in-test data, and structural integrity data" that can be downloaded directly to ground systems for analysis and response (Boeing C-17, 2006). The improved technology allowed the Dover AFB MXG to reduce its AMXS manning by approximately half (Losurdo, 2006). The F-22 promises to improve automated maintenance capability even further with an even more extensive built-in-test capability that extends to individual line-replaceable units and an Integrated Maintenance Information System that integrates aircraft maintenance data with the required Technical Orders and forms to act as a single source of information for the maintainer (F-22 Raptor, 2006). These features are projected to contribute to a 50% savings in total operational and support costs over the first 20 years of the platform's life cycle (F-22 Raptor, 2006). The potentially significant impact of IVHM on overall manpower requirements is depicted in Table 32, which applies varying degrees of IVHM-related manpower reductions to the baseline estimate of 1,636 personnel.

Table 32. Adjustments for IVHM Impact

Workcenter	IVHM, No Impact	IVHM, 10% Reduction	IVHM, 20% Reduction	IVHM, 50% Reduction
MXG Staff	50	**49**	**48**	**46**
MOS	132	132	132	132
MXS	916	**829**	**741**	**461**
MUNS	194	194	194	194
AMXS	344	**310**	**276**	**173**
MXG Total	1636	**1514**	**1391**	**1006**

Because an IVHM system reduces the requirements for troubleshooting and inspections, functions performed by the AMXS and MXS workcenters which comprise over 75% of the total MXG workforce, the potential manning impact of IVHM utilization is significant. As such, investment in IVHM technology presents a design alternative that yields a high cost savings in manpower.

Additional Sensitivity Analysis.

A range of MXG manning requirements was assessed by setting factor combinations to their highest and lowest values, yielding the results shown in Table 33.

Table 33. Establishing an MXG Range

Workcenter	All Factors Low	Fleet Size 6, All Others Low	Three Shifts, Fleet Size 6, All Others Low	Fleet Size 6, All Others High	All Factors High
MXG Staff	4	17	36	64	74
MOS	16	68	101	165	191
MXS	69	363	447	1274	1488
MUNS	24	97	147	239	280
AMXS	30	165	261	431	503
MXG Total	**143**	**710**	**992**	**2173**	**2536**

In addition to establishing the full range by setting all factors at their lowest and highest values, this calculation also established ranges of values for two major assumptions of this research: a fleet size of six vehicles and a fleet size of six vehicles with three-shift operations. While an MXG manned at 1,636 positions was considered to be the best estimate of manpower requirements, the size of the total workforce could range from 143 personnel for a single vehicle to over 2,500 personnel for a fleet of seven. For a six-RMLV fleet, personnel requirements for the MXG could be expected to fall between 710 and 2,173 total personnel, based upon research synthesizing Shuttle and aircraft maintenance requirements. An MXG with 710 personnel would support two shifts of operations. The range of requirements for an MXG supporting three shifts of operations was 922 to 2,173 total personnel.

In addition to these hand-selected factor-level combinations, six design points were sampled at random to generate additional data outside of those points considered relevant and interesting to this research process. The results for the six additional samples are summarized in Table 34.

Table 34. Random Sample of Design Points

Workcenter	Shifts = 3; Surface Area = .5; Complexity = 2.5; Fleet Size = 4	Shifts = 3; Surface Area = .5; Complexity = 1.5; Fleet Size = 4	Shifts = 2; Surface Area = 2; Complexity = 2.5; Fleet Size = 2
MXG Staff	40	32	15
MOS	109	88	41
MXS	496	393	259
MUNS	163	128	57
AMXS	288	230	98
MXG Total	**1096**	**871**	**470**
Workcenter	**Shifts = 3; Surface Area = 2.5; Complexity = 2.5; Fleet Size = 3**	**Shifts = 2; Surface Area = .5; Complexity = 2; Fleet Size = 3**	**Shifts = 3; Surface Area = 2; Complexity = 2.5; Fleet Size = 1**
MXG Staff	33	17	12
MOS	86	46	32
MXS	642	202	198
MUNS	125	69	46
AMXS	216	117	75
MXG Total	**1102**	**451**	**363**

When combined with the purposeful sampling of design points generated by this research, a regression analysis (Appendix J) yielded the following equation:

$$Y = 354.63(Shifts) + 66.77(Surface\ Area) + 483.48(Complexity) + 217.02(Fleet\ Size) - 1941.76$$

The analysis of this equation revealed, however, that the Surface Area variable was not significant in the regression (p-value = .39). The analysis was conducted again without the Surface Area Factor, resulting in the following equation:

$Y = 365.41(shift) + 513.15(complexity) + 217.95(fleet\ size) - 1913.36$

This equation can now be used to provide a manpower estimate for an RMLV MXG varying factor values.

In the next section, AFMS calculations were applied to determine the manning requirements for the remaining RMLV ground support workcenters.

Ground Support Workforce

RMLV Logistics Support Functions.

Remaining RMLV ground support functions operating under the LRS, as identified in Chapter VI, Analysis of Organizational Structure, were addressed by four manpower standards: Base Supply, responsible for all spares support (Air Force, AFMS 41A0, 2003: 1); Fuels Management, responsible for all petroleum, oil, lubricants, propellants, and cryogenics support (Air Force, AFMS 41D1, 2003: 1); Vehicle Maintenance, responsible for repair and maintenance of all vehicles and equipment (Air Force, AFMS 42B1, 2003: 1); and Vehicle Operations, responsible for all vehicle management and dispatch operations (Air Force, AFMS 42A1, 1997: 1). The direct application of these standards requires historical data in each of the functional areas that is not yet available for the RMLV. However, by applying parametric relationships to AFMS average man-hour calculations, the AFMS was executed to provide an estimate of ground support manning requirements. Appendix G contains the calculation process, average monthly man-hour summary, and applicable excerpt from the Standard Manpower Table for each AFMS.

For all standards, a MAF of 149.6 and an overload factor of 1.077 were utilized where required. These factors correspond to a normal 40-hour workweek (Air Force, AFI 38-201, 2003: 55). While RMLV support will be a 24-hour operation, each shift will work a normal 40-hour week, and multiple shifts were captured within the AFMS for each individual workcenter. This section applied AFMS calculations to evaluate the manpower requirements for each workcenter in turn, concluding with an overall assessment of the RMLV ground support workforce.

Base Supply.

The Base Supply workload factor is based on the average monthly number of transactions processed for due-out releases, establishing due-outs, issues from stock, receipts, turn-ins, and warehouse location changes (Air Force, AFMS 41A0, 2003: 4). This data would normally be available in a Consolidated Transaction History generated by the Standard Base Supply System database (Air Force, AFMS 41A0, 2003: 4). Since historical data was not yet available for the RMLV, the average monthly man-hours established in the AFMS for Materiel Requests (due-outs), Materiel from Stock (issues), Materiel Receipt (receipts and due-out releases), and Materiel Storage (warehouse locations changes) were used to approximate the average monthly man-hours an RMLV Supply function would devote to these transactions (Air Force, AFMS 41A0, 2003: 52).

Additionally, two variances were authorized to Whiteman AFB specifically to support the unique requirements imposed by Low Observable structural material. These variances were added to the average monthly man-hours for supply transactions, and the total was adjusted by the Complexity Factors identified in the previous section and a Fleet Size factor of 6/16. This parametric relationship was used because the number of spare parts required is impacted by the complexity and number of supported platforms. Table 35 lists the steps used to apply the Base Supply AFMS (central values in bold).

Table 35. Application of Base Supply Manpower Standard

Base Supply: AFMS 41AO			
Ref	**Action**	**Calculation**	**Derivation**
1.3.5, 1.4	Man-hour Equation	Y= .8529X	X = average monthly number of specified supply transactions
2.1	Step 1: Add 2 for flight supervision	2	
2.2	Step 2: Add 1 for flight administration	1	
2.3	Step 3: Add 1 for funds management	1	
2.4	Step 4: Determine after-hours support from Table 1	2.177	Assumes 1 flying squadron, 24-hour operations
2.5	Step 5: Determine average monthly transactions from CTH	Not Available	
2.6	Step 6: Compute Monthly Man-hours	8581.52	Total of average monthly process time for those processes assigned against the relevant transactions
	Apply Parametric	4827.11, **6436.14**, 8045.18	Adjusted by Vehicle Complexity (1.5, 2, 2.5) and Fleet Size (.375) parametric
2.7; A4.16	Step 7: Add applicable variance man-hours	5157.49, **6766.52**, 8375.56	+ 330.38 for Whiteman Low Observable Contract Support
2.8	Step 8: Divide man-hours by MAF	32.01, **42.00**, 51.98	MAF = 149.6, overload = 1.077
2.9	Step 9: Add fixed manpower from steps 1-4	38.187, **48.17**, 58.157	
2.10	Step 10: Exercise Participation Credit	Not Applicable	In this research, RMLV exercise participation is not addressed.
2.11	Step 11: Deployment Participation Credit	Not Applicable	RMLV is non-deployable.
2.12	**Step 12: Add results of steps 10 and 11 to step 9, and round up.**	**49**	Range is 39 to 59

The result of applying the AFMS for Base Supply operations was a workcenter staffed by 49 personnel broken down by rank and level of expertise in Table 36.

Table 36. RMLV Supply Support from Standard Manpower Table (Air Force, AFMS 41A0, 2003: 34)

Title	AFSC	Rank	Manpower Requirement
Supply	021S3	Capt	1
Supply	021S3	Lt	1
Supply Management Supt	2S0XX	CMSgt	0
Supply Management Supt	2S0XX	SMSgt	1
Supply Mgt Craftsman	2S07X	MSgt	2
Supply Mgt Craftsman	2S07X	TSgt	5
Supply Mgt Journeyman	2S05X	SSgt	12
Supply Mgt Journeyman	2S05X	SrA	15
Supply Mgt Apprentice	2S03X	A1C	12
Total			**49**

Fuels Management.

The Fuels Management workload factor is based on the historical monthly average of fuel receipts and fuel transfers (Air Force, AFMS 41D1, 2003: 3-4). Since this information was not yet available, the average monthly man-hours established in the AFMS for Receiving and Distribution (Air Force, AFMS 41D1, 2003: 38) were used to approximate the average monthly man-hours devoted to receipts and transfers.

In order to correctly size the Fuels Management flight, a parametric relationship was developed comparing the fuel loads of the B-2 and the Shuttle Orbiter Main Engines. The solid-fuel second stage was not assessed because it would not require fuels personnel support. The implications of a liquid-propellant second stage are addressed in Chapter VIII, Conclusions and Future Research. The resulting parametric relationship was:

535,000 lbs (SSME): 200,000 lbs (B-2) = 2.675

Accordingly, the average monthly man-hours from the AFMS were increased by a factor of 2.675. Sensitivity analysis was conducted using bounding values of 2 and 3.5. Table 37 summarizes the steps to apply the Fuels AFMS (central values are in bold).

Table 37. Application of Fuels Management Manpower Standard

Fuels Management: AFMS 41D1			
Ref	**Action**	**Calculation**	**Derivation**
1.3.8, 1.3.9.1 1.3.9.2	Man-hour Equation	Y = 948.758 + 1053.6149X1 + 97.5441X2	X1 = average monthly gallons of fuel received; X2 = average monthly number of fuel transfers
2.1.1	Step 1: Determine number of shifts	3	3 Shifts for 24-hour operations
2.1.2	Step 2: Determine type of delivery mode	Truck	All propellant deliveries at Vandenberg are by commercial trailer (30th Space Wing, 1998: 2)
2.1.3; 1.3.7	Step 3: Determine fractional manpower from Table 1 based on steps 1 and 2	5.33	
2.2.1-2.2.5	Determine values for X1 and X2 based on historical data	Not Available	
	Sum average monthly receiving and distribution man-hours; Apply Parametric	8426.20, **11270.04**, 14745.85	(Receiving (1535.59) + Distribution (2677.51)) * 2, 2.675, 3.5
2.2.6	Step 6: Calculate average monthly man-hours and divide by MAF	62.67, **81.68**, 104.91	Y=948.758 + 11270.04 (total avg monthly man-hours for receiving and distribution); MAF = 149.6
2.3.1	Step 1: Add steps 3 and 6	68.00, **87.01**, 110.24	
2.3.2	Step 2: Add 2 for overhead mgt	70.00, **89.01**, 112.24	
2.3.3	**Step 3: Add 1 for overhead admin**	71.00, **90.01**, 113.24	
2.3.4	Step 4: Add 14 for Resource Control Center	85.00, **104.01**, 127.24	
2.3.5	Step 5: Add 4 for Checkpoint Operation process	89.00, **108.01**, 131.24	
2.3.6	Step 6: Add 4 for Quality Control and Inspection process	93.00, **112.01**, 135.24	
2.3.7	Step 7: Add 2 for Fuels Flight Support process	95.00, **114.01**, 137.24	
2.3.8	Step 8: Calculated Variance man-hours divided by MAF	4.69	+701.76 for Cryogenics; MAF = 149.6
2.3.9	Step 9: Add Variance authorizations to step 7	99.69, **118.70**, 141.93	
2.3.10	Step 10: Exercise Participation Credit	N/A	In this research, RMLV exercise participation is not addressed
2.3.11	Step 11: Deployment Participation	N/A	RMLV is non-deployable.
2.3.12	**Step 12: Add results of steps 10 and 11 to step 9, and round up.**	**119**	Range is 100 to 142

The Fuels Management flight supporting the RMLV fleet would be composed of 119 personnel, with the rank and expertise levels described in Table 38.

Table 38. RMLV Fuels Support from Standard Manpower Table (Air Force, AFMS 41D1, 2003: 26)

Title	AFSC	Rank	Manpower Requirement
Supply Mgmt Officer	23S4	Maj	1
Supply Operations Officer	23S3	Capt	0
Fuels Manager	2F000	CMSgt	1
Fuels Superintendent	2F091	SMSgt	1
Fuels Craftsman	2F071	MSgt	8
Fuels Craftsman	2F071	TSgt	13
Fuels Journeyman	2F051	SSgt	25
Fuels Journeyman	2F051	SrA	35
Fuels Apprentice	2F031	A1C	33
Info Mgmt Journeyman	3A051	SSgt	1
Info Mgmt Journeyman	3A051	SrA	1
Total			**119**

Vehicle Maintenance.

The Vehicle Maintenance workload factor is based on the total number of vehicle and equipment authorizations on base, which are typically documented in a Vehicle Authorization List (Air Force, AFMS 42B1,2003: 3). Since this document has not yet been developed for the RMLV, the average monthly man-hours established in the AFMS for Refueling Vehicle and/or Equipment Maintenance and Repair, Special Purpose Vehicle and/or Equipment Maintenance and Repair, and General Purpose Vehicle and/or Equipment Maintenance and Repair (Air Force, AFMS 42B1,2003: 53) were used to approximate the average monthly man-hours that will be devoted to RMLV fleet maintenance. Man-hours for Fire Department Vehicles and 463L Materiel Handling Equipment Vehicles were not included in the calculation, as they are not specific to the RMLV, and were assumed to be supported by the existing Vehicle Maintenance structure at Vandenberg AFB or Cape Canaveral AFS. Finally, monthly man-hours were adjusted by the range of Complexity Factors identified in the previous section and a Fleet Size Factor of 6/16. This parametric was used because the number of vehicles and equipment required for ground support operations is impacted both by the number and complexity of the platforms supported.

Additionally, three workcenters within Vehicle maintenance required independent manpower calculations. Manning authorizations for the Maintenance Control and Analysis workcenter and the Material Control workcenter were derived from staffing patterns based on the total number of authorized vehicles (excluding equipment) on base. To apply these staffing patterns, the B-2 vehicle fleet size of 650 vehicles was used as a baseline estimate of total authorized vehicles (509th Logistics Readiness Squadron, 2006), and was adjusted by the range of Complexity Factors and a Fleet Size factor of 6/16 to approximate RMLV vehicle authorizations. The result was a total of 488 authorized vehicles as an input to the staffing pattern. This application also assumed that the number of authorized and assigned vehicles were equal. The final Vehicle Maintenance workcenter, Vehicle Maintenance Management, was determined from a staffing pattern based on the number of personnel authorized under the preceding calculations.

Table 39 summarizes the steps followed to apply the Vehicle Maintenance AFMS (central values are in bold).

Table 39. Application of Vehicle Maintenance Manpower Standard

Vehicle Maintenance: AFMS 42B1			
Ref	**Action**	**Calculation**	**Derivation**
1.3, 1.4	Man-hour Equation	Y = 4.6349X - 1513.41	X = total number of vehicle and/or equipment equivalents assigned to flight for maintenance
Table A5.1	Determine total average monthly man-hours	3881.50	Total of applicable avg monthly process times
	Apply Parametric	2183.34, **2911.13**, 3638.91	Complexity (1.5, 2, 2.5) and Fleet Size parametric (0.375)
2.1	Step 1: Compute equation.	669.93, **1397.72**, 2125.50	Y = adjusted avg monthly man-hours - 1513.41
2.2	Step 2: Determine variance man-hours	Not Applicable	
2.3-2.5	Steps 3-5: Determine contractor, civilan, foreign national positions	Not Applicable	
2.6	Step 6: Divide by MAF, round up	5, **10**, 15	Assume all military positions; MAF = 149.6
2.7	Step 7: Add civilian and military requirements	Not Applicable	
2.8	Step 8: Determine MC&A requirements using Tables 2 and 3	7	Authorized Vehicles = Assigned Vehicles = 650*2*0.375 = 488
2.9	Step 9: Determine Materiel Control requirements using Table 5	3	Assigned Vehicles = 488
2.10	Step 10: Determine VM Management requirements using Table 1	2	VM personnel = 10 + 7 + 3 = 20
2.11	**Step 11: Determine total VM flight requirements, summing steps 6, 8, 9, and 10**	**22**	Range is 17 to 27

The Vehicle Maintenance Flight supporting RMLV operations would require 22 personnel with the ranks and levels of technical expertise specified in Table 40.

Table 40. RMLV Vehicle Maintenance Support from Standard Manpower Table (Air Force, AFMS 42B1, 2003: 35)

Title	AFSC	Rank	Manpower Requirement
Veh Mx Craftsman	2T370	MSG	1
Veh Mx Craftsman	2T370	TSG	2
Veh Mx Journeyman	2T35X	SSG	6
Veh Mx Journeyman	2T35X	SRA	10
Veh Mx Apprentice	2T33X	A1C	3
Total			**22**

Vehicle Operations for Installations with Flying Missions.

The Vehicle Operations workload factor is based on total base military and civilian personnel authorizations (Air Force, AFMS 42A1, 1997: 2). In order to derive an estimate of total base population including the RMLV ground support organization, the current military and civilian base populations of Vandenberg AFB and Patrick AFB were combined with the previously determined RMLV MXG, Base Supply, Fuels, and Vehicle Maintenance requirements. Since supply, fuels, and vehicle maintenance functions are pre-existing at both locations, it was assumed that any flight management positions are already staffed, and only functional positions would be added to total flight authorizations. As a result, all positions above the rank of MSgt were subtracted from those flights. The resulting equations were:

3,331 (military) + 1,459 (civilian) + 1,634 (MXG) + 46 (Supply) + 116 (Fuesl) + 22 (VM) = 6608 (Friends of Vandenberg AFB, 2007)

Low value = 3,331 (military) + 1,459 (civilian) + 1,155 (MXG) + 37 (Supply) + 97 (Fuels) + 17 (VM) = 6,096

High value = 3,331 (military) + 1,459 (civilian) + 2,173 (MXG) + 54 (Supply) + 139 (Fuels) + 27 (VM) = 7,183

2,519 (military) + 1,071 (civilian) + 1,634 (MXG) + 46 (Supply) + 116 (Fuel) + 22 (VM) = 5408 (Hass, 2003: 183)

Low value = 2,519 (military) + 1,071 (civilian) + 1,155 (MXG) + 37 (Supply) + 97 (Fuels) + 17 (VM) = 4,896

High value = 2,519 (military) + 1,071 (civilian) + 2,173 (MXG) + 54 (Supply) + 139 (Fuels) + 27 (VM) = 5983

The average of the base totals, approximately 6,000 total base personnel, was utilized to calculate Vehicle Operations manpower requirements, as outlined in Table 41. Low and high averages of 5,500 and 6,580 were used to establish a range; central values are denoted in bold.

Table 41. Application of Vehicle Operations Manpower Standard

Ref	Action	Calculation	Derivation
2.3, 2.4	Man-hour Equation	Y = 1232.91 + 1.01X	X = total number of AF military and civilian authorizations, not including contractors
3.1	Step 1: Determine base population	5,500, **6,000**, 6,580	Average of Vandenberg/Patrick AFB populations with RMLV support manning added
3.2	Step 2: Compute man-hours	6787.91, **7292.91**, 7878.71	
3.3	Step 3: Divide by MAF, overload, round up	43, **46**,49	MAF = 149.6, overload = 1.077
3.4	**Step 4: Apply Variances and sum for total authorizations**	**46**	Range is 43 to 49

The Vehicle Operations flight supporting the RMLV would require 46 personnel with the rank structure and skill levels assigned in Table 42.

Table 42. RMLV Vehicle Operations Support from Standard Manpower Table (Air Force, AFMS 42A1, 1997: 3)

Title	AFSC	Rank	Manpower Requirement
Transportation	24T3	Capt	1
Vehicle Ops Manager	2T100	CMSgt	0
Vehicle Ops Superintendent	2T191	SMSgt	1
Vehicle Ops Craftsman	2T171	MSgt	2
Vehicle Ops Craftsman	2T171	TSgt	3
Vehicle Ops/Dispatch Journeyman	2T151	SSgt	8
Vehicle Ops/Dispatch Journeyman	2T151	SrA	15
Vehicle Ops/Dispatch Apprentice	2T131	A1C	15
Information Mgt Journeyman	3A051	SSgt	1
Total			**46**

Summary

In this chapter, RMLV ground support manpower requirements were determined using LCOM and AFMS calculation methods in accordance with AF policy. Calculations were largely based on B-2 support organizations, determined in Chapter VI, Analysis of Organizational Structure, to be the most appropriate comparison platform. Parametric relationships based on comparisons between B-2 and Shuttle data were used to adjust manpower calculations to appropriately account for the characteristics of a space launch vehicle, and sensitivity analyses were performed where possible to establish ranges of manpower values.

Ground support operations for an RMLV fleet will require a Maintenance Group staffed with between 922 and 2,173 personnel for 24-hour operations, and supply, fuels, and transportation manpower totaling between 199 and 277 personnel. Based on the best estimates of this research, the total support numbers include 1,636 MXG personnel and

236 LRS personnel. Assuming that the RMLV operates out of Vandenberg AFB or Patrick AFB, where the Logistics Readiness Squadron and Safety office are already established, calculated supervisory positions in these areas would not be required. This would result in a total impact to base population for RMLV ground support operations of 1,864 additional personnel. Chapter VIII, Conclusions and Future Research, will address the training and life cycle cost implications of these results, discuss the impact of design alternatives, and recommend areas for future research.

VIII. Conclusions and Future Research

By comparing current aircraft and Space Shuttle operations, it has been possible to estimate the size and organizational structure of an RMLV ground support workforce that will support the regeneration activities identified in the MILEPOST simulation model. This organization is designed to be attached to existing operations at Vandenberg AFB or Cape Canaveral AFS, and will consist of a Maintenance Group modeled after B-2 operations and a parametrically sized Logistics Readiness Squadron workforce that can be incorporated into an existing squadron. The anticipated organizational structure and manpower numbers, totaling 1,872 personnel, are depicted in Figure 37.

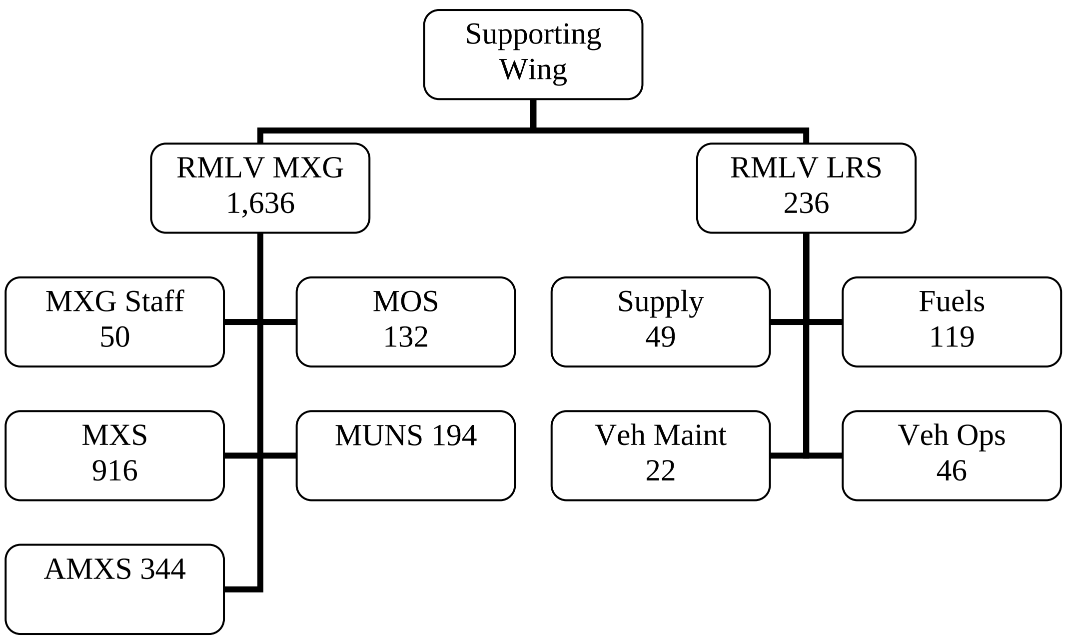

Figure 37. RMLV Ground Support Organization

While these numbers represent the baseline estimate of total logistics manpower requirements arrived at by this research process, a range of maintenance workforce values was also assessed to address variation in RMLV design factors.

Figure 38 depicts the evolution of the maintenance workforce as it has been transformed from supporting a B-2 unit in order to support a future RMLV unit. It is interesting to note the change in proportion of the individual maintenance workcenters.

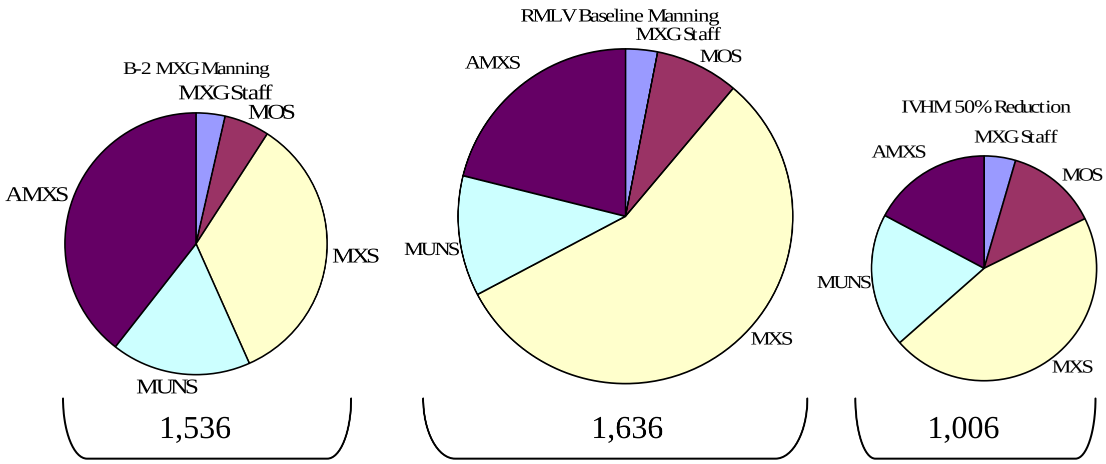

Figure 38: RMLV MXG Development

The AMXS workcenter supporting an RMLV fleet will comprise a much smaller percentage of total maintenance operations, while the MXS workcenter will make up a much greater portion of the MXG. The RMLV fleet is projected to be much smaller than the B-2 fleet, necessitating fewer flightline maintenance manning resources, while the increased maintenance requirements of the more complex propulsion system and structural elements require increased manning resources in the backshop. In addition, the MOS workcenter grows slightly in proportion due to the involvement of the Research Engineer section in the engineering support element of Shuttle propulsion operations. Finally, the MUNS workcenter decreases slightly due to reduced maintenance requirements associated with second stages and payloads that are delivered ready-to-integrate. If an IVHM system is incorporated that yields a 50% improvement in maintenance capability, the MXS and AMXS squadrons reduce proportionately in comparison to the other workcenters, and total manpower requirements reduce considerably.

Figure 39 depicts a range of MXG workforce sizes and compositions representing all factors at their lowest values, the lowest-value six-ship fleet supporting three-shift operations, and all factors at their highest values.

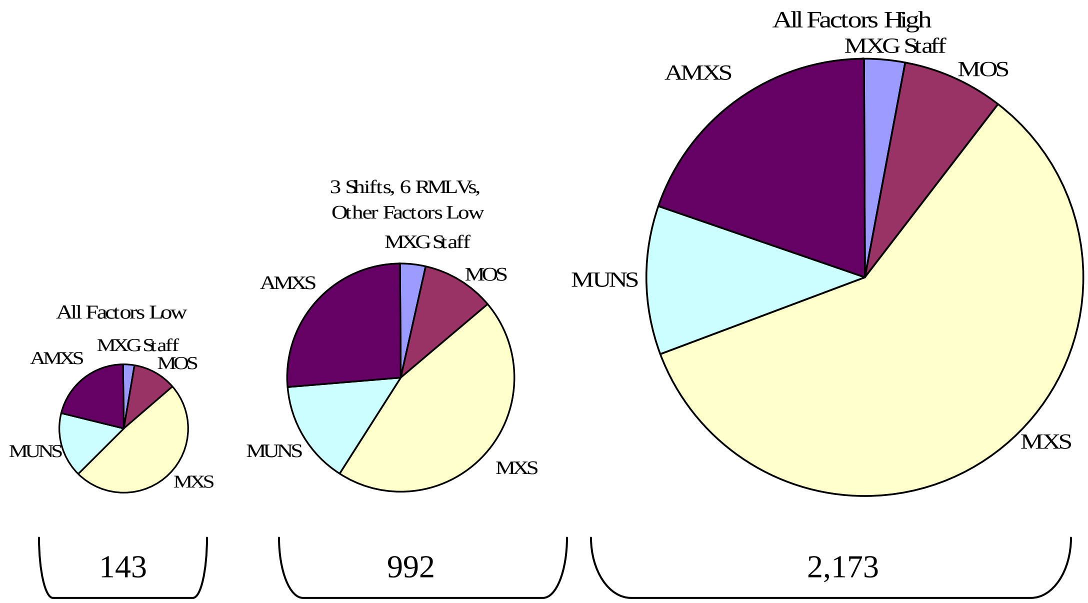

Figure 39. MXG Manpower Range

Without careful design consideration, a combination of large surface areas and significant complexity with a fleet size of six vehicles causes manpower requirements to inflate quickly. However, by maintaining design factors like size and complexity at low levels, even a full-sized fleet operating three shifts can achieve lower maintenance manpower requirements than the baseline estimate.

Additionally, logistics support manpower requirements can be expected to vary between 199 and 277 personnel for a fleet size of six RMLVs. These numbers are also affected by vehicle complexity and by size-related factors like fuel consumption.

Throughout the step-by-step manpower assessment and sensitivity analysis, it was clear that certain factors caused a greater impact on manpower numbers than others. Figure 40 provides a visual representation of the impact of combinations of tested factors on the manpower response variable.

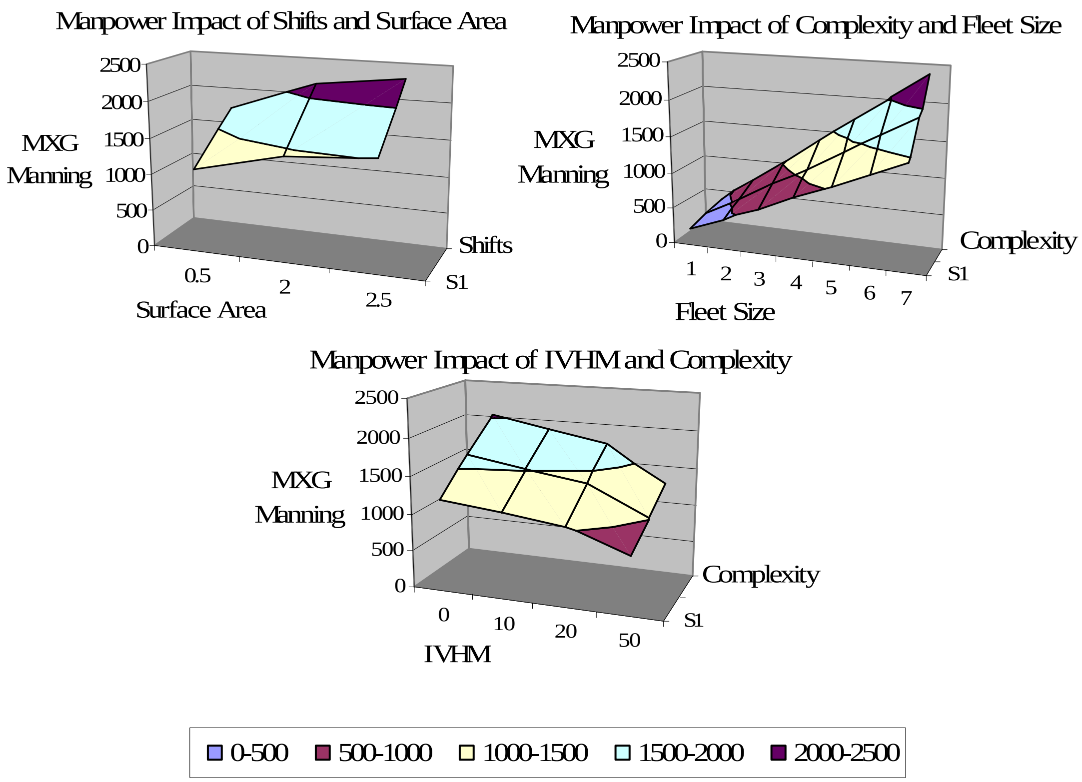

Figure 40. Impact of Test Factors on Manpower Requirements

These comparisons show that while the number of shifts and the relative surface area of the RMLV have some impact on total manpower numbers, the more dramatic changes are caused by adjustments in fleet size, relative vehicle complexity, and the incorporation of varying levels of IVHM. Design alternatives that address these factors will have the greatest impact on total logistics support manpower requirements.

To conclude the evaluation of RMLV ground support operations, this chapter will address the life cycle and training cost implications of the projected manpower, the impact of future design alternative decisions on this manpower estimate, and future research efforts that will further refine the logistics assessment of RMLV design candidates.

Life Cycle Cost

The life cycle costs associated with logistics manpower support for the RMLV are comprised mainly of personnel and training costs. AF Personnel Costs are derived from annual personnel budget planning factors, while estimates of the cost of training support are based on historical data regarding training support contracts established upon the introduction of new weapons systems into the AF inventory.

AF Cost of Personnel.

The AF maintains an estimate of the average annual cost of personnel by rank, attached at Appendix H, organized under three pay rate categories: Standard Composite Pay Rate w/PCS, Accelerated Annual Pay Rate per Workyear, and Accelerated Annual Pay Rate (Direct Workhour). Accelerated Annual Pay Rate (Direct Workhour) is to be used only when costing based on actual time worked. Accelerated Annual Pay Rate per Workyear, which "represents the total cost of one full-time military member," provides the most comprehensive estimate of annual cost and will be the pay rate used for this cost estimate (Air Force, AFI 65-503, 1994: 4).

The manpower output data generated by the LCOM report for MXG authorizations, which formed the basis for the RMLV MXG manpower estimate, is not detailed to the rank-level. In addition, the use of parametric relationships to size the workforce would require a new LCOM simulation to generate the rank structure associated with the adjusted estimate. As a result, average values for officer and enlisted personnel were utilized, with the assumption that there are six total officer positions for the central value of the manpower estimate: two at the MXG, and one each at the MOS, MXS, AMXS and MUNS agencies, assigned against the squadron Commander positions. The AFMS documents used to calculate LRS agency requirements designated rank-specific manpower structures, and specific annual cost data was assigned against these estimates. A summary of personnel cost calculations is presented in Table 43.

Table 43. Annual Cost of Logistics Ground Support Personnel

Org	Rank	Unit Cost (K)	Qty Low	Qty Avg	Qty High	Total Cost Low (K)	Total Cost Avg (K)	Total Cost High (K)
MXG	Officer	$128.32	5	**6**	8	$641.60	**$769.92**	$1,026.56
	Enlisted	$67.46	1150	**1630**	2165	$77,579.00	**$109,959.80**	$146,050.90
LRS	O-4 Major	$142.54	0	**1**	1	$0.00	**$142.54**	$142.54
	O3 Captain	$118.10	3	**2**	2	$354.30	**$236.20**	$236.20
	O2 Lieutenant	$99.36	0	**1**	2	$0.00	**$99.36**	$198.72
	E9 Chief Master Sergeant	$117.81	1	**1**	2	$117.81	**$117.81**	$235.62
	E8 Senior Master Sergeant	$101.73	3	**3**	3	$305.19	**$305.19**	$305.19
	E7 Master Sergeant	$90.24	11	**13**	15	$992.64	**$1,173.12**	$1,353.60
	E6 Technical Sergeant	$79.44	19	**23**	26	$1,509.36	**$1,827.12**	$2,065.44
	E5 Staff Sergeant	$69.49	45	**53**	57	$3,127.05	**$3,682.97**	$3,960.93
	E4 Senior Airman	$58.65	64	**76**	87	$3,753.60	**$4,457.40**	$5,102.55
	E3 Airman First Class	$50.91	53	**63**	82	$2,698.23	**$3,207.33**	$4,174.62
Total (K)			1354	**1872**	2450	$91,078.78	**$125,978.76**	$164,852.87

According to this estimate, an average personnel budget of approximately $126 billion per year would be required to staff the RMLV logistics ground support organization. By integrating the RMLV LRS agencies into an operational LRS at Vandenberg or Patrick AFB, the AF would save almost $1 billion (the sum of all LRS positions above the rank of Master Sergeant). The bulk of the personnel expenditure is concentrated on the sizeable MXG organization; any design or operational considerations that reduce the MXG footprint for RMLV support will greatly benefit the overall cost of the program.

Training Cost.

The cost of training personnel in RMLV-specific maintenance and equipment operations will be a significant portion of total life cycle cost. The AF currently has established training programs for each required AFSC; however, additional specialized training will be required to address the unique aspects of RMLV logistics support.

Historically, the introduction of new platforms into the AF inventory has been met with different solutions. When the B-2 became operational in 1993 (B-2 Spirit, 2007), Structural Repair personnel at Whiteman AFB completed specialized training in maintenance of Low Observable materials upon their arrival to the unit. This approach posed considerable challenges to the maintenance operation. While the training program itself was based upon accurate contractor maintenance data, the opportunity to actively apply individual maintenance techniques was infrequent due to relatively low sortie rates and low occurrences of individual types of failure. Additionally, the AF personnel rotation system resulted in high turnover rates and a high percentage of personnel with low experience levels at any given time. This led to a Structural Repair workforce that experienced difficulty in achieving proficiency, which lengthened repair times, and drove

Whiteman AFB leadership to seek a training solution. The solution manifested itself in the form of a partnership with Northrop Grumman, and a contract for production personnel, who had gained LO repair proficiency on the production line, to integrate into the Structural Repair organization to provide continuity and expertise (B-2 Visit, 2006). The dissimilarity of the RMLV from other AF weapons systems may necessitate a similar arrangement to address repair proficiency, and the cost of such a contract will need to be figured into total life cycle cost.

With the introduction of newer platforms like the C-17 and F-22, procurement of contracted maintenance support entails significant initial and recurring costs. In support of the C-17, for example, the AF first awarded a comprehensive five-year maintenance support contract to United Industrial Corporation in 1997 (United Industrial Wins, 2007). Follow-on contracts continued with a $22.3 million contract to upgrade trainers to Block 12 in 2001 (United Industrial Wins, 2007) and a $5.6 million upgrade contract in 2003, which brought the total contract value to $206.4 million over those first six years (United Industrial Corporation, 2007). Upgrades are a continuing necessity, however, and in 2005, the AF awarded a $70 million contract for the production of six new maintenance trainers to be used at new maintenance training facilities at Travis AFB, Hickam AFB, and Elmendorf AFB in 2008 (Air Force Buys, 2007). Subsequently, in 2006, the AF awarded a $30.2 million contract for two additional trainers to be delivered in 2009 and 2010, with an option for a $14.9 million aircraft engine maintenance trainer (United Industrial's AAI Services Subsidiary Receives, 2007).

The F-22A, approved for full-rate production in 2005 (F-22A Raptor, 2007), will be supported by maintainers trained in a newly-constructed $19.7 million training facility beginning in 2008 (Officials Break Ground, 2007). Follow-on costs for contracted training systems and upgrades are yet to be determined, but may easily follow the pattern established by the C-17. In 2002, Boeing contracted with Link Simulation and Training for $55.9 million over two contracts to build full mission trainers, with the potential for executing an eight-contract series valued at over $200 million (Link Simulation & Training, 2007). In 2006, a new contract was established with United Industrial Corporation for $48.5 million to produce maintenance training systems specific to landing gear, armament, and aft fuselage components (United Industrial's AAI Services Corporation, 2007), and just this year, an additional $6.7 million contract was awarded to United Industrial for an upgraded landing gear trainer (United Industrial's AAI Services Subsidiary Wins, 2007). These costs occur in addition to the funding required for facility construction and modification, and represent a significant, on-going logistics cost consideration.

To summarize, the cost implications for the RMLV ground support workforce can be expected to include approximately $630 billion in AF cost of personnel and well over $200 million in training support costs for the first five years of operation.

Impact of Design Alternatives

As the design process for the RMLV matures, certain initial design alternatives can result in significant impacts to the manpower estimates derived in this research. Specifically, the choice of method for the RMLV to return to the launch-site will determine TPS requirements, which will directly impact the Structural Repair manpower support, the most significant single contributor to total manning requirements. Additionally, an Integrated Vehicle Health Management (IVHM) system will impact total

MXG manpower requirements, reducing overall manpower required for system troubleshooting. Finally, decisions regarding the use of expendable or reusable second stages, and liquid or solid second-stage propellant, will significantly impact total manpower requirements.

Jet Fly-Back vs. Rocket Boost-Back.

Current Shuttle TPS maintenance operations form a significant portion of total man-hours, and the impact of a Shuttle-like TPS system was examined in Chapter VII, Manpower Assessment. This type of TPS requirement is consistent with a vehicle that, following separation, "aerodynamically decelerates to subsonic speeds, turns, and uses airbreathing jet engines to cruise back to the spaceport for a powered landing" (Snead, 2006: 32). Using this model of RMLV operations, known as the jet fly-back model, TPS maintenance requirements using current technologies would be very similar to those experienced by the Shuttle (Rooney, 2005: 9), and could result in significant increases to manpower estimates, particularly in the Structural Repair workcenter.

Another option under consideration for the RMLV return-to-launch-site activity involves turning the booster after separation, executing a controlled burn until the vector aligns with the launch site, and concluding with an unpowered reentry and glide back for horizontal landing (Hellman, 2005: 4). The primary advantage to this approach, known as the rocket boost-back model, is that significantly less thermal protection would be required in comparison to the jet fly-back method (Hellman, 2005: 14). Additionally, the vehicle would require more fuel to execute the second controlled burn, but would not require jet engine support (Hellman, 2005: 14). This design alternative has the potential to significantly decrease the MXG footprint of RMLV operations, particularly in the arena of Structural Repair.

Structural Repair support is a significant contributor to total workforce requirements for both the B-2 and the Shuttle. In fact, when the B-2 Structural Repair personnel implemented new technology for maintenance of their LO structures, the fleet experience a 15% increase in airframe availability and a 50% decrease in maintenance man-hours expended per flying hour (Boston, 2006). Similarly, improved technologies or design alternatives affecting RMLV TPS requirements will significantly impact Structural Repair manpower requirement. Additionally, since fuels and engine workcenters are impacted by return-to-launch-site alternatives, implementing a rocket boost-back design method would require recalculation of the manpower estimate.

IVHM.

The type and extent of IVHM system utilized in the RMLV has the potential to impact total MXG manning numbers. The manpower estimate in this research is based on the B-2's OBTS, which collects maintenance indicator data during flight operations for analysis and action on the ground (Air Combat Command, 2006: 29). However, integrated health management systems as envisioned for developing aerospace platforms extend beyond simply collecting diagnostic information, and offer prognostic assessment and automated inspections (Ofsthun, 2002: 22). An IVHM system performing the full range of functions would reduce the number of AMXS and MXS personnel required for trouble-shooting and inspections, and would require recalculation of the manpower estimate.

Second Stage Alternatives.

This research has been based on the assumption that the RMLV will be a hybrid launch vehicle, with a reusable first stage and an expendable second stage. As such, the manning requirements for the second stage are combined with the manning requirements for the payload, and treated as a workcenter that essentially stores, inspects, and then integrates the second stage and payload in the same manners as the B-2 Munitions Squadron handles its weapons and armament. A reusable second stage would effectively double most workcenter requirements, adding another vehicle that requires the complete range of recovery, maintenance, and pre-launch operations, while the workforce responsible for payload storage, inspection, and integration would decrease slightly.

Given an expendable second stage, the choice between liquid and solid propellant remains a significant factor in manpower requirements. Current manpower requirements are based on liquid fuel support only for the first stage of the RMLV, while the second stage is assumed to be delivered ready-for-use, essentially modeled after a solid-propellant system. If an expendable stage is chosen that requires liquid propellant and on-site fueling, the fuels support for storage and distribution would double.

In summary, manpower determinations in this research are modeled on an RMLV with a reusable first stage utilizing a combination of rocket and jet propulsion, and an expendable second stage delivered and stored ready-for-use. Some degree of IVHM is included in the manpower estimate, modeled on the B-2 experience with its OBTS. Different design decisions in these areas will have a significant impact on the manpower estimates, and results will have to be recalculated. In the next section, opportunities for future research will be discussed that will allow timely and accurate recalculation to account for these and other alternative decisions that will occur throughout the design phase.

Future Research

The primary purpose of this research was to provide foundational information that future researchers can use to improve the manpower fidelity of the MILEPOST model. A crucial aspect of future research will be the ability to transform the manpower estimate derived in this thesis into a MILEPOST resource allocation method, resulting in the capability within MILEPOST to generate manpower support estimates for different design alternatives. The AF LCOM manpower tool provides insight on the process of allocating maintenance resources to individual simulation activities. Additionally, to round out the fidelity of the MILEPOST model, future research will be required to address similar estimation and allocation projects for facility, equipment, and materiel resources. MILEPOST will then provide a comprehensive model that allows the generation of turnaround time and total resource consumption based on scenarios specifying design considerations and operational requirements.

MILEPOST activities have been designated in the manner that best reflects ground processing activities that affect turnaround time. These activities do not lend themselves to a one-to-one correspondence with manpower, as activities often require multiple personnel, and personnel from multiple AFSCs. Additionally, AF maintenance activities are organized by Work Unit Code (WUC), a five-digit designator that describes the “sub-system problems and repair actions associated with a piece of equipment or a system” (Air Force, AFI 21-103, 2005: 46). WUCs allow maintenance organizations to identify specific components that are causing system downtime, and will not correspond directly either to MILEPOST activities or to specific manpower requirements. Therefore, in order to allocate the logistics manpower resources identified in this research to individual MILEPOST activities, a conversion process will have to be developed. This conversion process can be based upon the LCOM solution to allocating maintenance manpower resources.

LCOM requires users to submit historical maintenance data to derive input information for the simulation. This historical data for existing airframes is easily extracted from the Core Automated Maintenance System, and is converted by the LCOM Data Preparation Subsystem and Data Structuring Subsystem into the format depicted in Figure 41.

JCN	WUC	TAKEN	DATE	START	STOP	TIME	CREW	REASON
171152	46A00	Y	6017	900	1130	2.5HR	2	Troubleshooting
171152	24AD0	S	6027	1530	1730	2.0HR	2	Remove for Access
171152	46ADE	R	6028	800	1830	10.5HR	2	Remove/Replace
171152	24AD0	S	6028	2230	30	2.0HR	2	Reinstall After Access
171152	11GSE	Q	6029	230	300	0.5HR	2	Close after Access
171152	46A00	X	6029	330	530	2.0HR	2	Functional Check

Mean Time To Repair 10.5hr (0800-1830)
Mean Corrective Time 19.5hr (2.5+2.0+10.5+2.0+0.5+2.0)
Mean Discrepancy Length 288.5hr (0900 on 6017 to 0530 on 6029)

- DPSS converts MDC action code Y to LCOM Action Code T – So LCOM task T46A00 is 2.5hr with a crew of 2
- DPSS sums and converts MDC action codes S to LCOM Action Code X – So LCOM task X24ADO is 4.0hr with a crew of 2
- DPSS sums and converts MDC action codes Q+R to LCOM Action Code R – So LCOM task R46A00 is 11.0hr with a crew of 2
- DPSS Converts MDC action code X to LCOM Action Code V - So LCOM task V46A00 is 2.0hr with a crew of 2

Figure 41. Maintenance Data Collection Format
(Aeronautical Systems Center, 2004: 62)

The activities listed above constitute one complete repair activity, or task, from start to finish, assuming there are no time gaps between subsequent tasks (Aeronautical Systems Center, 2004: 64). Each action taken code is converted into an LCOM activity code with its associated WUC. For the maintenance actions listed above, the LCOM series of tasks is F46A00, T46A00, X24AD0, R46A00, and V46A00 (Aeronautical Systems Center, 2004: 64) This series within LCOM generates a total repair time for a crew of two for this repair activity based on corresponding aircraft maintenance activities and their historical completion times. If the simulation is run with unlimited resources, the total task time for the sequence should equal the mean corrective time, 19.5 hours (Aeronautical Systems Center, 2004: 65). If constraints on personnel, facilities, and equipment are introduced series time will increase, approaching 288.5 hours as resources are constrained to match the exact availability at the location that generated the maintenance data (Aeronautical Systems Center, 2004: 65).

To accomplish a similar function in MILEPOST, future researchers will first need to establish a list of MILEPOST tasks and corresponding MILEPOST Action Codes, compiled based on the activities listed in the MILEPOST model. Subsequently, researchers will need to establish a WUC listing to differentiate among workcenters performing the same Action Code on different systems. For example, troubleshooting in the engine backshop will need to be distinguished by WUC from troubleshooting during aircraft recovery. The workcenter identification portion of the WUCs will be based upon the required workcenters identified in the logistics support organizational structure identified in this research. Finally, each Action Code/WUC combination utilized in the sequence of MILEPOST regeneration activities will require a repair time assignment based on a given crew size, determined by more detailed research based on aircraft and Shuttle data. At this point, the Action Code/WUC assigned to each MILEPOST regeneration activity will have associated manpower resources, allowing users to determine total manpower support associated with a given vehicle design candidate.

In order to provide more detailed manpower information, each LCOM task is assigned specific AFSCs, as shown in Figure 42.

AFSC	QTY	TASK(S)		
2BTTL	6	BATTLE_DAMAGE		
PC	6	BATTLE_DAMAGE	JPARK_AC_IN_SHELTER	
	5	DOWNLOAD_HUNG_ORD	JTAXI	
	4	JEND_OF_RUNWAY_CHK	LOADBOMB	LOADMBRK
		PHASE1	UNBOMB	UNBMRK
	3	JTANKS	LOADGUN	LOAD_CHAFF_DISPENS
	2	DO_PREFLIGHT	JHALON_SERVICE	JHYDRAZINE_SERVICE
		REFUEL	REPLACE_HOOK_POINT	
	1	START_ENGINES	THRUFLT	

Figure 42. Task Report with AFSC by Quantity
(Aeronautical Systems Center, 2004: 214)

AFSCs assigned for the purposes of the LCOM simulation may or may not correspond to AF standard AFSCs. For example, in the Joint Service FX-99 Generic Fighter Model described in the User's Manual, all personnel are consolidated under six generalized AFSCs, created based upon the location of maintenance; for example, 1FLTL is the AFSC for all flightline maintenance (Aeronautical Systems Center, 2004: 460). Alternate crew configurations may be identified for the same task, with alternate completion times if necessary; for example, a less-experienced crew assigned to the same activity could result in a longer repair time (Aeronautical Systems Center, 2004: 69).

In order to utilize this method in MILEPOST, future researchers will need to designate AFSCs against each MILEPOST Action Code/WUC combination utilized by the regeneration activities. This research provides a comprehensive pool of AFSCs that will be utilized; future research will need to determine, based on aircraft and Shuttle data, the number of personnel within a given AFSC that are required by each task. At this point in the research, each MILEPOST regeneration activity will be allocated AFSC-specific resources, enabling the simulation to provide detailed workforce requirements as an output, and allowing constraints to be adjusted by AFSC. This research may begin with generalized AFSC assignments, as depicted in the LCOM FX-99 Model, that will become more refined as additional maintenance data becomes available.

A similar research process will be required for facilities, equipment, and materiel resources such as propellant and spares to first estimate baseline requirements and then assign them as allocable resources for MILEPOST simulation runs. Since a level of depot maintenance was assumed in the manpower analysis, based on the three-level maintenance assumptions in the B-2 LCOM manpower data, future research will also need to address the depot maintenance manpower requirements to support a fleet of RMLVs. Finally, an analysis of basing should be conducted to determine the optimal basing location for the RMLV fleet.

Summary

The MILEPOST model provides a simulation framework to estimate regeneration times for Reusable Military Launch Vehicles with varying design characteristics. While critical, regeneration time is not the only factor under consideration in the design phase of a weapons system. Logistics support requirements comprise a significant portion of total life cycle costs; as a result, this research set out to determine a baseline estimate of the logistics ground support workforce requirements for the RMLV, given current design and operational parameters. It has been determined that a fleet of six RMLVs, operating out of either Vandenberg or Patrick AFB, can be adequately supported under the existing AFSC structure with approximately 1,870 personnel aligned under a Maintenance Group and Logistics Readiness Squadron consisting of Base Supply, Fuels, Vehicle Maintenance, and Vehicle Operations Flights. The estimated cost of personnel and training for this workforces is $630.2 billion for the first five years.

As a baseline estimate, personnel numbers and total cost will vary considerably as the RMLV's design and operational characteristics are finalized. The MILEPOST model was designed as a method to account for these changes and provide updated regeneration time data as scenario factors and design characteristics are adjusted. As a result, the primary purpose of establishing this baseline estimation was to identify workcenter and AFSC resources that can be allocated within MILEPOST using a method modeled after the LCOM simulation process. Future research based on this information will result in an RMLV simulation model that addresses both manpower and regeneration time estimates for a variety of RMLV design candidates engaged in a range of operational scenarios.

Appendix A. MILEPOST AFSC Matrix

Recovery Operations (Martindale, 2006)

Landing, Taxi, and Initial Safing (0)		
Activity	*Platform*	*AFSC*
Landing, Wheels Stop	N/A	N/A
RMLV Taxi to Recovery Apron	F-16	2AXXX
Reaction Jet Drive and Drag Chute Safing	Shuttle	shortfall
APU Shutdown Not Automatic	Shuttle	2A6X6
APU Shutdown	Shuttle	2A6X6
APU Shutdown Automatic	Shuttle	2A6X6
LOX Safing	Shuttle	2A6X4
Does Design Include Hypergolics? Yes (1)	Shuttle	2A6X6
Hypergolic Detection Self-Contained on RMLV? Yes	Shuttle	2A6X6
Ground Crew Receives Safety Self-Assessment	Shuttle	2A6X6
Pass Safety Assessment	Shuttle	2A6X6
Hypergolic Detection Self-Contained on RMLV? No	Shuttle	2A6X6
Forward Safety Assessments	Shuttle	1S0X1, 2A6X6
Aft Safety Assessments	Shuttle	1S0X1, 2A6X6
Pass Safety Assessment	Shuttle	1S0X1, 2A6X6
Doesn't Pass Safety Assessment	Shuttle	1S0X1, 2A6X6
Mx Delay Safety for Haz Gas	Shuttle	1S0X1, 2A6X6
Does Design Include Hypergolics? No (2)	Shuttle	N/A
Maintenance Actions Required to Prepare RMLV for Transportation (3)		
Activity	*Platform*	*AFSC*
Send to Haz Gas Purge	Shuttle	shortfall
Haz Gas Purge Req'd? Yes	Shuttle	shortfall
Connect Haz Gas Monitor and Purge Ducts	Shuttle	shortfall
Initiate Haz Gas Purge and Monitor	Shuttle	shortfall
Haz Gas Purge Req'd? No	Shuttle	N/A
Send to Coolant GSE	Shuttle	shortfall
RMLV Designed with Hot Structures? Yes	Shuttle	shortfall
RMLV Designed with Hot Structures? No	Shuttle	shortfall
Connect Coolant GSE	Shuttle	shortfall

Secure NH3 Coolant, Activate Ground Cooling	Shuttle	shortfall
Send to Lock Pins and Vent Plugs	F-16	2AXXX
Install Ground Lock Pins and Vent Plugs	F-16	2AXXX
Send to Inspection and Configuration		2AXXX
Superficial TPS and Debris Inspection	Shuttle	2AXXX
Configure for Handover to Spaceport Ground Control	Shuttle	2AXXX
External Stores and Final Safety Call (4)		
Activity	*Platform*	*AFSC*
Can RMLV Return with External Stores? Yes	F-16	2WXX1
Is RMLV Returning with External Stores? Yes	F-16	2WXX1
Position External Store GSE	F-16	2WXX1
Separate External Stores	F-16	2WXX1
Load and Remove External Stores	F-16	2WXX1
Can RMLV Return with External Stores? No	Shuttle	N/A
Is RMLV Returning with External Stores? No	Shuttle	N/A
Safe to Proceed with Total Downgrade? No		1S and 2A
Mx Delay for Safety Downgrade		1S and 2A
Send to Safing Sequence (5)		N/A
Safing Sequence (6)		
Activity	*Platform*	*AFSC*
OMS RCS System Safing	Shuttle	2A6X1
Tank Vent RMLVME	Shuttle	shortfall
MPS Configuration	Shuttle	2A6X1
Does Design Include Hypergolics 2? Yes	Shuttle	2A6X6 (EPU on the F-16)
Hydrozine Circulation Pump Safing	Shuttle	2A6X6 (EPU on the F-16)
Hypergolic Detection Self-Contained on RMLV 2? Yes	Shuttle	2A6X6 (EPU on the F-16)
Stow Air Data Probes	Shuttle	2A6X6 (EPU on the F-16)
Does Design Include Hypergolics 2? No	Shuttle	N/A
Hypergolic Detection Self-Contained on RMLV 2? No	Shuttle	N/A
INS Recorder and CW Safing	Shuttle	2A5X3

RMLV Preparation for Transportation (Simultaneous with Safing Sequence) (6)		
Activity	*Platform*	*AFSC*
Send to Vacuum Vent Duct Inerting	Shuttle	shortfall
Vacuum Duct Inerting Required? Yes	Shuttle	shortfall
Initiate Vacuum Duct Inerting	Shuttle	shortfall
Vacuum Duct Inerting Required? No	Shuttle	N/A
Send to Protective Cover Installation	Shuttle	2AXXX
MPS and RMLV Protective Covers Required? Yes	Shuttle	2AXXX
Install MPS and RMLV Protective Covers	Shuttle	2AXXX
MPS and RMLV Protective Covers Required? Yes	Shuttle	2AXXX
Send to Position Tow Coupling	Shuttle	2A6X2
Position Hookup Tug	Shuttle	2A6X2
Monitor On-Board Systems	Shuttle	2A6X2
Final Tow Preparations (7)		
Activity	*Platform*	2A6X2
Attach Tow Tug to RMLV	Shuttle	2A6X2
Check Tow Tug Connections	Shuttle	2A6X2
Final Tow Preps	Shuttle	2A6X2
Towing Operations (8)		
Activity	*Platform*	*AFSC*
Tow RMLV	Shuttle	2A6X2
RMLV Exit to Mx	Shuttle	2A6X2

Ground Maintenance Operations (Pope, 2006)

Disconnection from the Launch Vehicle		
Activity	*Platform*	*AFSC*
Connect to Stage 1	aircraft (B-2)	2A6X2
Transport to Mx Bay	aircraft	2A6X2, 2AXXX
Position Stage 1 in Mx Bay	aircraft	2AXXX
Grounding Procedures	aircraft	2AXXX
Disconnect from Stage 1	aircraft	2A6X2
Diagnostics		
Activity	*Platform*	*AFSC*
Interrogate Mx Reporter	aircraft	2A5X3
Position Maintenance Stands	aircraft	2AXXX
Electrical Connections 2	aircraft	2AXXX
Battery Testing	aircraft	2A6X6 (E&E)

Batteries Good? No	aircraft	2A6X6 (E&E)
Replace Batteries	aircraft	2A6X6 (E&E)
Batteries Good? Yes	aircraft	2A6X6 (E&E)
Charge Batteries	aircraft	2A6X6 (E&E)
MA Parallel Processes	N/A	N/A
Avionics Testing	aircraft	2A5X3
Flight Controls	aircraft	2A5X3
Sensor Equipment	aircraft	2A5X3
Upper Stage Testing		
Activity	*Platform*	*AFSC*
Upper Stage Electrical Connecting Point Testing	Shuttle	2A6X6 (E&E)
Parallel Process 1	N/A	N/A
Parallel Process 2	N/A	N/A
Drag Chute	Shuttle	shortfall
Visual Check TPS	Shuttle	2A7X3
Tile and Blanket R-Square	Shuttle	2A7X3
Thermal Barrier Repair	Shuttle	2A7X3
Gap Filler R-Square	Shuttle	2A7X3
Sealant Application	Shuttle	2A7X3
Curing	Shuttle	2A7X3
Recheck TPS	Shuttle	2A7X3
RMLV Systems Check	Aircraft	2AXXX
Waterproof TPS	Shuttle	2A7X3
Parallel Process 2	N/A	N/A
Modular Motor R-Square? Yes	Shuttle	2A6X1
Connect Motor Stand	Shuttle	2A6X1
Disco Electronics from Stage 1	Shuttle	2A6X1
Disco Mechanics from Stage 1	Shuttle	2A6X1
Remove Motor	Shuttle	2A6X1
Disco Stand	Shuttle	2A6X1
Place New Motor and Stand	Shuttle	2A6X1
Mech Connect Motor to Stage 1	Shuttle	2A6X1
Elect Connect Motor	Shuttle	2A6X1
Connection Test	Shuttle	2A6X1
Disco Stand and Remove	Shuttle	2A6X1
Modular Motor R-Square? No	shuttle	2A6X1
Engine Diagnostics	shuttle	2A6X1
Pumps and Fuel System	shuttle	2A6X4

Engine Controls	shuttle	2A6X1
Nozzles	shuttle	2A6X4
Linkage	shuttle	2A6X1
Number of Motors = 3? Yes		2A6X1
Engine Checkout	shuttle	2A6X1
Number of Motors = 3? No		2A6X1
Engine Check Good? No, Return to Modular Motor R-Square?	shuttle	2A6X1
Engine Check Good? Yes	shuttle	2A6X1
Parallel Process 1	N/A	N/A
Parallel Process 2	N/A	N/A
Stage 2 Mechanical Connections	aircraft	2A5X1
Stage 2 Area Hardware	aircraft	2A5X1
Buffer Plug R-Square	aircraft	2A5X1
Parallel Process 3	N/A	N/A
Lubricator Check	aircraft	2A6X5
Filters	aircraft	2A6X5
LRU R-Square	aircraft	varies by LRU
Parallel Process 3	N/A	N/A
Hydraulic Condition	aircraft	2A6X5
Filters	aircraft	2A6X5
Parallel Process 2	N/A	N/A
Preplanned Maintenance	aircraft	varies by action
TCTO Actions	aircraft	varies by action
Landing Gear and Tires	Shuttle/Bomber	2A6X6,
Move to Integration? No	shuttle	2AXXX
MA Storage Reinspection	shuttle	2AXXX
Move to Integration? Yes	shuttle	2A6X2

Pre Launch Operations (Stiegelmeier)

Preintegration (Simultaneous with RMLV Maintenance)		
Activity	*Platform*	*AFSC*
Preintegration? Yes	ICBM	N/A
Attach Handling Fixture to Payload	EELV	2T2X1, 2A6X2
Align Payload with Second Stage	EELV	2T2X1, 2A6X2
Make Mechanical Connections	EELV	2T2X1, 2A6X2

Make Electrical Connections	EELV	2A6X6
Second Stage and Payload Integration Check	ICBM	2A6X6
Preintegration? No, Proceed to F	Delta II	N/A
Vehicle Integration, Preliminary Considerations		
Activity	*Platform*	*AFSC*
(F) Integrate on Pad? Yes	Delta II	N/A
Move Vehicle to Launch Pad, Proceed to G	Delta II	2A6X2
Integrate on Pad? No	EELV	N/A
Vehicle in Integration Facility? Yes, Proceed to (H)	EELV	N/A
Vehicle in Integration Facility? No	EELV	N/A
Move Vehicle to Integration Facility, Proceed to (H)	EELV	2A6X2
(G) Vehicle Integration, Integrate on Pad		
Activity	*Platform*	*AFSC*
Preintegration? Second Stage and Payload Preintegrated	ICBM	N/A
Attach Handling Fixture to RMLV	Delta II	2A6X2
Erect and Position RMLV	Delta II	2A6X2
Attach Handling Fixture to Second Stage/Payload	Delta II	2A6X2
Position Second Stage/Payload	Delta II	2A6X2
Make Mechanical Connections	Delta II	2T2X1, or 2A6X2
Make Electrical Connections	Delta II	2A6X6
Preintegration? No Preintegration	Delta II	N/A
Attach Handling Fixture to RMLV	Delta II	2A6X2
Erect and Position RMLV	Delta II	2A6X2
Attach Handling Fixture to Second Stage	Delta II	2T2X1, 2A6X2
Erect and Position Second Stage	Delta II	2A6X2
Make Mechanical Connections	Delta II	2T2X1, or 2A6X2
Make Electrical Connections	Delta II	2A6X6
First, Second Stage Integration Check	Delta II	2A6X6
Payload Clean Room Required? Yes	Delta II	N/A
Prep Clean Room	Delta II	
Payload Clean Room Required? No	Delta II	N/A
Attach Payload Handling Equipment	Delta II	2A6X2
Lift and Align Payload	Delta II	2A6X2

Make Mechanical Connections	Delta II	2T2X1, or 2A6X2
Make Electrical Connections	Delta II	2A6X6
Entire Vehicle Integration Check, Proceed to I	Delta II	2A6X6
(H) Vehicle Integration, Integrate off Pad		
Activity	*Platform*	*AFSC*
Preintegration? Second Stage and Payload Preintegrated	ICBM	N/A
Horizontal or Vertical Integration? Vertical	Atlas V	N/A
Attach Handling Fixture to RMLV	Atlas V	2A6X2
Erect and Position RMLV on MLP	Atlas V	2A6X2
Attach Handling Fixture to Second Stage/Payload	Atlas V	2A6X2
Erect and Position Second Stage/Payload	Atlas V	2A6X2
Make Mechanical Connections	Atlas V	2T2X1, or 2A6X2
Make Electrical Connections	Atlas V	2A6X6
Preintegration? Second Stage and Payload Preintegrated	ICBM	N/A
Horizontal or Vertical Integration? Horizontal	Delta IV	N/A
Attach Handling Equipment to Second Stage/Payload	Delta IV	2T2X1
Position/Align Second Stage/Payload	Delta IV	2T2X1
Make Mechanical Connections	Delta IV	2T2X1, or 2A6X2
Make Electrical Connections	Delta IV	2A6X6
Preintegration? No Preintegration		N/A
Horizontal or Vertical Integration? Vertical	Atlas V	N/A
Attach Handling Fixture to RMLV	Atlas V	2A6X2
Erect and Position RMLV on MLP	Atlas V	2A6X2
Attach Handling Fixture to Second Stage	Atlas V	2A6X2
Erect and Position Second Stage	Atlas V	2A6X2
Make Mechanical Connections	Atlas V	
Make Electrical Connections	Atlas V	2A6X6
Preintegration? No Preintegration		N/A
Horizontal or Vertical Integration? Horizontal	Delta IV	N/A
Attach Handling Equipment to Second Stage	Delta IV	2T2X1
Position/Align Second Stage	Delta IV	2T2X1
Make Electrical Connections	Delta IV	2A6X6
Preintegration? No Preintegration	Delta II	N/A
First and Second Stage Integration Check	EELV	2A6X6

Launch Now? No	Shuttle	N/A
Storage	Shuttle	2A6X2
Reaccomplish Preflight and Additional Mx	Shuttle	2AXXX
Launch Now? Yes	EELV	N/A
Install Payload Now or On Pad? On Pad, Go to Load Hypergolic Fuel	Delta IV	N/A
Install Payload Now or On Pad? Now	Atlas V	N/A
Payload Clean Room Required? Yes		N/A
Prep Clean Room		???
Payload Clean Room Required? No		N/A
Attach Payload Handling Equipment	Atlas V	2T2X1
Position and Align Payload	Atlas V	2T2X1
Make Mechanical Connections	Atlas V	2T2X1, or 2A6X2
Make Electrical Connections	Atlas V	2A6X6
Entire Vehicle Integration Check	Atlas V	2A6X6
Launch Now? No	Shuttle	N/A
Storage	Shuttle	2A6X2
Reaccomplish Preflight and Additional Mx	Shuttle	2AXXX
Launch Now? Yes	EELV	N/A
Load Hypergolic Fuel? Yes	Shuttle	N/A
Load Hypergolic Fuel	Shuttle	2F0X1
Load Hypergolic Fuel? No	EELV	N/A
Ordnance Installation? Yes	Shuttle	N/A
Install Ordnance	Shuttle	2WXX1
Ordnance Installation? No	Shuttle	N/A
Final Closeouts and Transport Preparations	Shuttle	2AXXX
Attach Transporter	Shuttle	2A6X2
Transport Vehicle to Pad, Proceed to J	Shuttle	2A6X2
(J) Launch Pad Operations for Vehicle Not Integrated on Pad		
Activity	*Platform*	*AFSC*
Vertical or Horizontal Integration? Horizontal	Delta IV	N/A
Attach Erecting Mechanism? Yes	Zenit 2	N/A
Attach Erecting Mechanism	Zenit 2	2A6X2
Attach Erecting Mechanism? No	Delta IV	N/A
Erect Vehicle and Secure to Launch Platform	Delta IV	2A6X2
Move Transporter/Erecting Mechanism Away from Pad	Delta IV	2A6X2
Vertical or Horizontal Integration? Vertical	Atlas V	N/A
Install Payload on Pad? Yes	Delta II	N/A
Payload Clean Room Required? Yes	Delta II	N/A
Prep Clean Room		???

Payload Clean Room Required? No	Delta II	N/A
Attach Payload Handling Equipment	Delta II	2A6X2
Lift and Align Payload	Delta II	2A6X2
Make Mechanical Connections	Delta II	2T2X1, or 2A6X2
Make Electrical Connections	Delta II	2A6X6
Entire Vehicle Integration Check, Proceed to I	Delta II	2A6X6
Install Payload on Pad? No, Proceed to I	Atlas V	N/A
(I) Launch Pad Operations		
Activity	*Platform*	*AFSC*
Umbilical Options 1	Shuttle	N/A
Propellant Connections	Shuttle	2A6X4
Umbilical Leak Check	Shuttle	2A6X4
Electrical and Comm Connections	Shuttle	2A6X6
Verify Electrical and Comm Connectivity	Shuttle	2A6X6
Umbilical Options 2	Atlas V	N/A
Propellant Connections	Atlas V	2A6X4
Umbilical Leak Check	Atlas V	2A6X4
Umbilical Options 3 -- no connections required	Zenit 2	N/A
Hypergolic Fuel? Yes	Shuttle	N/A
Load Hypergolic Fuel	Shuttle	2F0X1
Hypergolic Fuel? No	EELV	N/A
RP-1? Yes	Atlas V/Zenit 2	N/A
Which Stages Get RP-1? First Only	Atlas V	N/A
Fuel RP-1 First Stage	Atlas V	2F0X1
Which Stages Get RP-1? First and Second	Zenit 2	N/A
Parallel? Yes	Zenit 2	N/A
Parallel RP-1 Fueling	Zenit 2	N/A
Fuel RP-1 First Stage	Zenit 2	2F0X1
Fuel RP-1 Second Stage	Zenit 2	2F0X1
End RP-1 Fueling	Zenit 2	N/A
Parallel? No	Zenit 2	N/A
Fuel RP-1 First Stage	Zenit 2	2F0X1
Fuel RP-1 Second Stage	Zenit 2	2F0X1
RP-1? No	Shuttle	N/A
Ordnance on Pad? Yes	Shuttle	N/A
Install/Arm Ordnance	Shuttle	2WXX1
Ordnance on Pad? No		N/A
Final TPS Inspection, Proceed to K	Shuttle	2AXXX
(K) Launch Pad Operations, Propellant Loading		
Activity	*Platform*	*AFSC*

Stages in Parallel, Fuel and Oxidizer in Parallel	HLV	2F0X1
Stage 1/Stage 2	HLV	2F0X1
Oxidizer/Fuel	HLV	2F0X1
LOX Chill/Fuel Chill	HLV	2F0X1
Load LOX/Load Fuel	HLV	2F0X1
End Propellant Loading	HLV	2F0X1
Stages in Parallel, Fuel and Oxidizer Not in Parallel	HLV	2F0X1
Stage 1/Stage 2	HLV	2F0X1
LOX Chill	HLV	2F0X1
Load LOX	HLV	2F0X1
Fuel Chill	HLV	2F0X1
Load Fuel	HLV	2F0X1
End Propellant Loading	HLV	2F0X1
Stages Not in Parallel, Fuel and Oxidizer Not in Parallel	HLV	2F0X1
RMLV LOX Chill	HLV	2F0X1
Load LOX RMLV	HLV	2F0X1
RMLV Fuel Chill	HLV	2F0X1
Load Fuel RMLV	HLV	2F0X1
Second Stage LOX Chill	HLV	2F0X1
Load LOX Second Stage	HLV	2F0X1
Second Stage Fuel Chill	HLV	2F0X1
Load Fuel Second Stage	HLV	2F0X1
End Propellant Loading	HLV	2F0X1
Terminal Countdown	Shuttle	2AXXX (MOC)
Launch	N/A	N/A

Appendix B. Aircraft Maintenance Workcenters Omitted from RMLV Organization

Function	*Justification*
Non-Applicable B-2 Functions	
MS, Egress Section	No crew to require Egress equipment support
MS, Survival Equipment	No crew to require Survival Equipment support
MUNS, Munitions Materiel	Requirement specifically for a munitions accountabilty officer
MUNS, Munitions Accountability	Requirements specifically to maintain a munitions accountability automated system
MUNS, Mobility Plans	No mobility commitment
MUNS, Production	No production of payloads or second stages, only reception and maintenance
MUNS, Conventional Maintenance	Specific to maintenance performed on conventional munitions
MUNS, Precision Guided Munitions	Specific to maintenance performed on precision-guided munitions
MUNS, Special Weapons	Flight maintains nuclear and other specialized weapons
MUNS, NOCM	Nuclear Ordnance Commodity Management
AMXS, MXAB	Entire AMU deleted. Only one required to support RMLV fleet.
Non-Applicable MQ-1 Functions	
AMXS, Mission Flight	Primarily responsible for maintenance of Ground Control Station and Predator Primary Satellite Link, systems that do not apply to the MILEPOST-modeled portion of RMLV ground operations

Appendix C. Adjustment for Variances, Overhead, and Shifts

Workcenter	Responsibility	LCOM Total	Variances not Authorized	Total - Variances	Overhead Adjustments	Total * Overhead Adjustment	Total * Shift Adjustment
Note: Any fraction of a manpower result is rounded up.							
Note: Functional workcenter manning supports an operational function rather than a certain number of personnel.							
MXG/CC	Group Commander and Staff	8		8	71%: MXG supports AMXS/MOS/MUNS/MXS. The total of these 4 squadrons adjusted for RMLV workcenters is 1052, while the total for the B-2 is 1482. The RMLV workcenter requirements, therefore, are 71% of B-2 requirements.	6	9
MXG/MXL	Loading Standard/Lead Crews train/evaluate all payload maintenance and operations	15		15	71%	11	17
MXG/MXQ	Quality Assurance	31		31	71%	23	35
MXG Total		**54**		**54**		**40**	**61**
MOS/CC/CCQ	Squadron Commander, Staff, and Orderly Room	5		5	100%: No change, no MOS workcenters omitted.	5	8
MOS/MXOO	Maintenance Operations, supervises next 5 sections	2		2	100%	2	3
MOS/MXOOA	Analysis of Maintenance Information Systems	11	-1, no support provided to tenants	10	Functional workcenter, not adjusted.	10	15
MOS/MXOOC	CIT/CEPS section provides 24/7 software analysis support for On-Board Test System	11		11	Functional workcenter, not adjusted.	11	17
MOS/MXOOE	Overall management for engines and engine parts	5		5	Functional workcenter, not adjusted.	5	8
MOS/MXOOM	Maintenance Operations Center coordinates aircraft maintenance with flying and support agencies	18	-1, operations centers not geographically separated	17	Functional workcenter, not adjusted.	17	26
MOS/MXOOP	Plans, Scheduling, and Documentation coordinates maintenance scheduling actions and maintains historical documentation systems	7		7	Functional workcenter, not adjusted.	7	11
MOS/MXOP	Plans and Resources manages manning and facilities	4		4	100%	4	6
MOS/MXOR	Research Engineer	10		10	Functional workcenter, not adjusted.	10	15
MOS/MXOT	Maintenance Training Flight	13		13	100%	13	20
MOS Total		**86**		**84**		**84**	**129**
MXS/CC/CCQ	Squadron Commander, Staff, and Orderly Room	8	-1 no Personnel Reliability Program (PRP) (specific to nuclear weapons)	7	95%: MXS numbers adjusted for RMLV workcenters total 501, while B-2 MXS totals 525. The RMLV requirement is 95% of the B-2 requirement.	7	11
MXS/MXM	Maintenance Squadron Supervision provide technical supervision for maintenance production	8		8	95%	8	12
MXS/MXMC	Accessories Flight includes Electric/Environmental, Fuels, Pneudraulics, and Egress (omitted)	2		2	Functional workcenter, not adjusted.	2	3
MXS/MXMCE	Electrical/Environmental	12		12	Functional workcenter, not adjusted.	12	18

Workcenter	Responsibility	LCOM Total	Variances not Authorized	Total - Variances	Overhead Adjustments	Total * Overhead Adjustment	Total * Shift Adjustment
MXS/MXMCF	Fuels	20		20	Functional workcenter, not adjusted.	20	30
MXS/MXMCP	Pneudraulics includes pneumatics and hydraulics	9		9	Functional workcenter, not adjusted.	9	14
MXS/MXMF	Fabrication Flight includes Metals Technology, Non-destructive Inspection, Structural Repair, and Survival Equipment (omitted)	2		2	Functional workcenter, not adjusted.	2	3
MXS/MXMFM	Metals Technology	9		9	Functional workcenter, not adjusted.	9	14
MXS/MXMFN	Non-destructive Inspection	12		12	Functional workcenter, not adjusted.	12	18
MXS/MXMFS	Structural Repair is the largest section because they perform all of the intensive low-observable material maintenance	184		184	Functional workcenter, not adjusted.	184	276
MXS/MXMG	Aerospace Ground Equipment flight	99		99	Functional workcenter, not adjusted.	99	149
MXS/MXMP	Propulsion Flight includes Jet Engine Intermediate Maintenance, Test Cell, Support Equipment, and Accessory sections	1		1	Functional workcenter, not adjusted.	1	2
MXS/MXMPJ	Jet Engine Intermediate Maintenance	22		22	Functional workcenter, not adjusted.	22	33
MXS/MXMPT	Test Cell includes operational checks, adjustments, and minor repairs	12		12	Functional workcenter, not adjusted.	12	18
MXS/MXMPS	Propulsion Support provides parts and tools support	8		8	Functional workcenter, not adjusted.	8	12
MXS/MXMT	Maintenance Support Flight includes Inspection and Wheels & Tires	1		1	Functional workcenter, not adjusted.	1	2
MXS/MXMTC	Inspection	29		29	Functional workcenter, not adjusted.	29	44
MXS/MXMTR	Wheels & Tires	28		28	Functional workcenter, not adjusted.	28	42
MXS/MXMV	Avionics, includes test station	36		36	Functional workcenter, not adjusted.	36	54
MXS Total		**502**		**501**		**501**	**755**
MUNS/CC/CCQ	Squadron Commander, Staff, and Orderly Room; the following munitions functions would apply to the second stage/payload for the RMLV	7	-1 no PRP	6	64%: MUNS numbers adjusted for RMLV workcenters total 169, compared to 265 positions for the B-2. RMLV requirements are 64% of B-2 requirements.	4	6
MUNS/MXW	Munitions Supervision provides technical oversight of munitions production	3		3	64%	2	3
MUNS/MXWCB	Munitions Inspection	3		3	Functional workcenter, not adjusted.	3	5
MUNS/MXWCC	Munitions Storage and Handling	17		17	Functional workcenter, not adjusted.	17	26
MUNS/MXWK	Munitions Systems Flight includes Munitions Control, CAS (omitted), Plans & Scheduling, and Plans and Mobility (omitted)	2		2	64%	2	3
MUNS/MXWKA	Munitions Control provides centralized coordination, planning, and direction	12		12	Functional workcenter, not adjusted.	12	18
MUNS/MXWKC	Plans & Scheduling	2		2	Functional workcenter, not adjusted.	2	3

Workcenter	Responsibility	LCOM Total	Variances not Authorized	Total - Variances	Overhead Adjustments	Total * Overhead Adjustment	Total * Shift Adjustment
MUNS/MXWP	Munitions Production Flight includes Conventional Munitions Maintenance, Precision Guided Munitions (omitted), Handling/Line Delivery, Equipment Maintenance, and Training	2		2	64%	2	3
MUNS/MXWPA	Conventional Maintenance assembles, tests, and repairs munitions (as stages will be integrated, tested, possibly undergo minor repairs)	22		22	Functional workcenter, not adjusted.	22	33
MUNS/MXWPB	Line Delivery	12		12	Functional workcenter, not adjusted.	12	18
MUNS/MXWPD	Munitions Support Equipment is separate from AGE, responsible for all munitions-specific handling and support equipment	5		5	Functional workcenter, not adjusted.	5	8
MUNS/MXWPT	Munitions Training	4		4	64%	3	5
MUNS/MXWR	Armament Systems Flight focuses on repair and inspection of aircraft and equipment components for loading munitions	17		17	Functional workcenter, not adjusted.	17	26
MUNS/MXWSS	Weapons Support performs supply functions	28		28	Functional workcenter, not adjusted.	28	42
MUNS/MXWSW	Weapons Maintenance	33		33	Functional workcenter, not adjusted.	33	50
MUNS Total		**169**		**168**		**164**	**249**
AMXS/CC/CCQ	Squadron Commander, Staff, and Orderly Room	9	-2 no PRP	7	50%: AMXS supervision is reduced by half since only one AMU is required for RMLV maintenance.	4	6
AMXS/MXA	Maintenance Supervision provides technical supervision for maintenance production	9		9	50%	5	8
AMXS/MXAA	Aircraft Maintenance Unit Supervision	19		19	100%: This supervision is specific to the single AMU, whose manpower did not change.	19	29
AMXS/MXAAA	Aircraft Section provides first-level maintenance associated with ground handling and servicing	78		78	Functional workcenter, not adjusted.	78	117
AMXS/MXAAF	Support Sections ensurex support equipment/supply support is available	18		18	Functional workcenter, not adjusted.	18	27
AMXS/MXAAS	Specialists include Engines, Electrics/Environmental, Pneudraulics, and Avionics personnel for troubleshooting and on-aircraft repairs	88		88	Functional workcenter, not adjusted.	88	132
AMXS/MXAAW	Weapons loaders, maintainers, and expediters who load munitions onto the aircraft	91		91	Functional workcenter, not adjusted.	91	137
AMXS Total		**312**		**310**		**303**	**456**
MXG Total		**1155**		**1117**		**1092**	**1650**

Appendix D. Percent Contribution of B-2 Workcenters

Unit	Workcenter	Workcenter Title	Manpower Requirement	% Total Manpower
509 MXG	CC	Commander	8	0.52%
	MXL	Loading Standard	7	0.46%
	MXLA	Lead Crew A	4	0.26%
	MXLB	Lead Crew B	4	0.26%
	MXQ	QA	31	2.02%
		509 MXG Tot	**54**	**3.52%**
509 MOS	CC	Commander	2	0.13%
	CCQ	Orderly Room	3	0.20%
	MXOO	Maint Ops	2	0.13%
	MXOOA	Analysis	11	0.72%
	MXOOC	CIT/CEPS	11	0.72%
	MXOOE	Engine Mgt	5	0.33%
	MXOOM	MOC	18	1.17%
	MXOOP	PS&D	7	0.46%
	MXOP	Plans & Resources	4	0.26%
	MXOR	Research Engineer	10	0.65%
	MXOT	Maintenance Tng	13	0.85%
		509 MOS Tot	**86**	**5.60%**
509 MS	CC	Commander	1	0.07%
	CCQ	Orderly Room	7	0.46%
	MXM	Maintenance Supervision	8	0.52%
	MXMC	Accessories	2	0.13%
	MXMCE	Elec/Enviro	12	0.78%
	MXMCF	Fuels	20	1.30%
	MXMCG	Egress	16	1.04%
	MXMCP	Pneudraulic	9	0.59%
	MXMF	Fabrication Flight	2	0.13%
	MXMFE	Survival Equip	7	0.46%
	MXMFM	Metals Tech	9	0.59%
	MXMFN	NDI	12	0.78%
	MXMFS	Structural Repair	184	11.98%
	MXMG	AGE Flight	99	6.45%
	MXMP	Propulsion Flight	1	0.07%
	MXMPS	Support/Supply Sect	8	0.52%
	MXMPJ	JEIM (Jet Engine Intermediate Mx)	22	1.43%
	MXMPT	Test Cell	12	0.78%
	MXMT	Maintenance Support	1	0.07%
	MXMTC	Aircraft Inspection	29	1.89%
	MXMTR	Wheel & Tire	28	1.82%
	MXMV	Avionics Flight	36	2.34%
		509 MS Total	**525**	**34.18%**
509 MUNS	CC	Commander	4	0.26%
	CCQ	Orderly Room	3	0.20%
	MXW	Munitions Supervision	3	0.20%
	MXWC	Munitions Materiel: MASO	3	0.20%
	MXWCA	Muns Accountability: CAS	6	0.39%
	MXWCB	Muns Inspection	3	0.20%
	MXWCC	Muns Storage/Handling	17	1.11%
	MXWK	Muns Systems	2	0.13%
	MXWKA	Muns Control	12	0.78%

Note: Shaded lines indicate functions that comprise more than 1% of total maintenance manpower, and were considered significant.

Unit	Workcenter	Workcenter Title	Manpower Requirement	% Total Manpower
	MXWKB	Mobility Plans	3	0.20%
	MXWKC	Plans & Scheduling	2	0.13%
	MXWP	Muns Production	2	0.13%
	MXWPA	Conventional Maintenance	22	1.43%
	MXWPB	Line Delivery	12	0.78%
	MXWPC	Precision Guided Muns	75	4.88%
	MXWPD	Muns Support Equip	5	0.33%
	MXWPT	Combat Muns Tng	4	0.26%
	MXWR	Armament Systems Flight	17	1.11%
	MXWS	Special Weapons	7	0.46%
	MXWSK	NOCM	2	0.13%
	MXWSS	Weapons Spt	28	1.82%
	MXWSW	Weapons Maintenance	33	2.15%
		509 MUNS total	**265**	**17.25%**
509 AMXS	CC	Commander	1	0.07%
	CCQ	Orderly Room	8	0.52%
	MXA	Maintenance Supervision	9	0.59%
(13BS)	MXAA	Aircraft Maintenance	19	1.24%
	MXAAA	Aircraft	78	5.08%
	MXAAF	Support	18	1.17%
	MXAAS	Specialist	88	5.73%
	MXAAW	Management	2	0.13%
	MXAAW	Weapons Loading	75	4.88%
	MXAAW	Weapons Maintenance	12	0.78%
		Weapons Expediters	2	0.13%
(393 BS)	MXAB	Aircraft Maintenance	19	1.24%
	MXABA	Aircraft	78	5.08%
	MXABF	Support	18	1.17%
	MXABS	Specialist	88	5.73%
	MXABW	Management	2	0.13%
	MXABW	Weapons Loading	75	4.88%
	MXABW	Weapons Maintenance	12	0.78%
		Weapons Expediters	2	0.13%
		509 AMXS Total	**606**	**39.45%**
Grand Total			**1536**	**100.00%**

Note: Shaded lines indicate functions that comprise more than 1% of total maintenance manpower, and were considered significant.

Appendix E. Alignment of Shuttle Disciplines/System Codes with B-2 LCOM Workcenters

Discipline	*System Code*	*Workcenter*	*Justification*	*Source*
Command, Control, & Health Management	DPS: Orbiter Data Processing System	MOS, CIT/CEPS	Responsible for Orbiter Data Processing System, which is comparable to the B-2 Onboard Test Systems and RMLV IVHM	LCOM report, 29
Command, Control, & Health Management	INS: Orbiter Instrumentation Systems	MXS, Accessories Flight, Electrics/ Environmental	Responsible for maintenance of electrical components; workcenter consists of 2A6X6, responsible for instrumentation panels	LCOM report, 48; AFECD, 26
Command, Control, & Health Management	SOF: Software	MXS, Avionics Flight	Workcenter consists of 2A0X1, responsible for upload of appropriate software	AFECD, 4
Communications	COM: Orbiter Communication Systems	MXS, Avionics Flight	Avionics flight is responsible for communcation systems	AFECD, 3
Environmental Control & Life Support	ECL: Environmental Control (Orbiter Cooling & Life Support)	MXS, Accessories Flight, Electrics/ Environmental	Workcenter is responsible for environmental systems	LCOM report, 48
Ground Systems & Facilities	GSE: Ground Support Equipment (non-specific)	MXS, AGE Flight	Workcenter is responsible for powered and non-powered ground equipment, except for specialized equipment for munitions, propulsion systems, ground vehicles, and avionics	LCOM report, 57
Guidance, Navigation, & Flight Controls	GNC: Guidance, Navigation, & Control Systems	MXS, Avionics Flight	Avionics flight is responsible for navigation, guidance, and control systems	AFECD, 3
Payload Accomodations	PLO: Payload Installation/Removal Operations	AMXS, Weapons	Responsible for loading and removal of munitions payloads	LCOM report, 43
Power Management	OTC: Orbiter Test Conductor Ops (Console Ops)	MOS, CIT/CEPS	Monitoring hardware/software aboard the orbiter itself; OBTS monitoring is closest parallel to IVHM monitoring	The Space Shuttle Launch Team; LCOM report, 29
Power Management	APU: Auxiliary Power Unit (APU)	MXS, Accessories Flight, Electrics/ Environmental	Workcenter consists of 2A6X6, responsible for maintenance of auxiliary power units	AFECD, 26
Power Management	EPD: Electrical Power Distribution	MXS, Accessories Flight, Electrics/ Environmental	Workcenter responsible for electrical components	LCOM report, 48
Power Management	OEL: Orbiter Electrical	MXS, Accessories Flight, Electrics/ Environmental	Workcenter responsible for electrical components	LCOM report, 48

Discipline	System Code	Workcenter	Justification	Source
Power Management	FCP: Fuel Cell Systems	MXS, Accessories Flight, Fuel Systems	Workcenter responsible for repairs, functional checks, servicing and inspection of fuel systems	LCOM report, 49
Power Management	HYD: Hydraulic Systems (Orb & SRB)	MXS, Accessories Flight, Pneudraulics	Workcenter responsible for hydraulics; consists of 2A6X5, Aircraft Hydraulic Systems	LCOM report, 51; AFECD, 25
Propulsion	SME: SSME Engineering	MOS, Research Engineer	Workcenter responsible for all the engineering supt	LCOM report, 34
Propulsion	MPS: Main Propulsion Systems	MXS, Propulsion Flight	Workcenter responsible for on- (Test Cell) and off-aircraft (JEIM) engine test, maintenance, and repair	LCOM report, 58
Propulsion	OMS-RCS: Orbital Maneuvering System-Reaction Control System	MXS, Propulsion Flight	As specialized engines, these would fit under propulsion	
Safety Management & Control	PVD: Orbiter Purge, Vent and Drain Systems	MXS, Accessories Flight, Fuel Systems; MXG, QA	Safety is not separated in an MXG; so, I assigned these to their functional area, but also to QA for oversight; purge function only occurs within 2A6X4, Aircraft Fuel Systems	AFECD, 24
Safety Management & Control	MPS: Main Propulsion Systems	MXS, Propulsion Flight; MXG, QA	Safety is not separated in an MXG; so, I assigned these to their functional area, but also to QA for oversight	
Safety Management & Control	SME: SSME Engineering (safety purges)	MXS, Propulsion Flight; MXG, QA	Safety is not separated in an MXG; so, I assigned these to their functional area, but also to QA for oversight; on this one, since it's purging engines, I gave it to propulsion instead of the engineers	
Structures, Mechanisms & Vehicle Handling	VPL: Vehicle Payload Operations	AMXS, Weapons	Responsible for loading and removal of munitions payloads	LCOM report, 43
Structures, Mechanisms & Vehicle Handling	OSO: Orbiter Systems Observer	MOS, MOC	Based on the summary of Direct Work Content provided in the NASA Technical Paper, OSO is responsible for activites related to tracking the movement and positioning of the orbiter for maintenance; this function is accomplished for aircraft by the MOC	NASA TP, 166; LCOM report, 31

Discipline	***System Code***	***Workcenter***	***Justification***	***Source***
Structures, Mechanisms & Vehicle Handling	QC: Quality Engineering	MXG, QA	Workcenter resonsible for Quality Assurance	LCOM report, 24
Structures, Mechanisms & Vehicle Handling	OHE: Orbiter Handling Equipment	MXS, AGE Flight	Responsible for ground equipment	LCOM report, 57
Structures, Mechanisms & Vehicle Handling	GSE: Ground Support Equipment (non-specific)	MXS, AGE Flight	Responsible for ground equipment	LCOM report, 57
Structures, Mechanisms & Vehicle Handling	OPT: Optical Systems	MXS, Avionics Flight	Avionics specialties and Integrated Avionics AFSC (2A5X3) are the only ones that mention maintaining optical systems	AFECD, 3, 9, 17
Structures, Mechanisms & Vehicle Handling	MEQ: Mechanical Systems	MXS, Fabrication Flight, Metals Technology	Workcenter responsible for manufacture and repair of aircraft parts, assemblies, and tools	LCOM report, 54
Structures, Mechanisms & Vehicle Handling	STR: Orbiter Structures	MXS, Fabrication Flight, Structural Repair	Workcenter responsible for on- and off-aircraft repair of structural components	LCOM report, 56
Structures, Mechanisms & Vehicle Handling	PYR: Pyrotechnic Systems	MXS, Fabrication Flight, Survival Equipment	Only AFSC 2A7X4 deals with pyrotechnics	AFECD, 31
Thermal Management	ECL: under Thermal Mgt, it's the Freon and water cooling loops	MXS, Accessories Flight, Electrics/Environmental	Workcenter consists of AFSC 2A6X6, responsible for liquid cooling systems	AFECD, 26
Thermal Management	TPS: Orbiter Thermal Protection--Tile	MXS, Fabrication Flight, Structural Repair	Workcenter consists of 2A7X3 responsible for all structural parts and components, various materials	LCOM report, 56; AFECD, 30
Thermal Management	TCS: Orbiter Thermal Protection--Blankets	MXS, Fabrication Flight, Structural Repair	Workcenter consists of 2A7X3 responsible for all structural parts and components, various materials	LCOM report, 56; AFECD, 30

Appendix F. MXG Parametric Adjustments

Workcenter	Responsibility	LCOM Total	Variances not Authorized	Total - Variances	Overhead Adjustments
Note: Any fraction of a manpower result is rounded up.					
Note: Functional workcenter manning supports an operational function rather than a certain # of personnel.					
MXG/CC	Group Commander and Staff	8		8	71%: MXG supports AMXS/MDS/MUNS/MXS. The total of these 4 squadrons adjusted for RMLV workcenters is 1052, while the total for the B-2 is 1482. The RMLV workcenter requirements, therefore, are 71% of B-2 requirements.
MXG/MXL	Loading Standard/Lead Crews train/evaluate all payload maintenance and operations	15		15	71%
MXG/MXQ	Quality Assurance	31		31	71%
MXG Total		54		54	
MDS/CC/CCQ	Squadron Commander, Staff, and Orderly Room	5		5	100%: No change, no MDS workcenters omitted.
MDS/MXOO	Maintenance Operations, supervises next 5 sections	2		2	100%
MDS/MXOOA	Analysis of Maintenance Information Systems	11	-1, no support provided to tenants	10	Functional workcenter, not adjusted.
MDS/MXOOC	CIT/CEPS section provides 24/7 software analysis support for On-Board Test System	11		11	Functional workcenter, not adjusted.
MDS/MXOOE	Overall management for engines and engine parts	5		5	Functional workcenter, not adjusted.
MDS/MXOOM	Maintenance Operations Center coordinates aircraft maintenance with flying and support agencies	18	-1, operations centers not geographically separated	17	Functional workcenter, not adjusted.
MDS/MXOOP	Plans, Scheduling, and Documentation coordinates maintenance scheduling actions and maintains historical documentation systems	7		7	Functional workcenter, not adjusted.
MDS/MXOP	Plans and Resources manages manning and facilities	4		4	100%
MDS/MXOR	Research Engineer	10		10	Functional workcenter, not adjusted.
MDS/MXOT	Maintenance Training Flight	13		13	100%
MDS Total		86		84	

Workcenter	Responsibility	LCOM Total	Variances not Authorized	Total - Variances	Overhead Adjustments
MXS/CC/CCQ	Squadron Commander, Staff, and Orderly Room	8	-1 no Personnel Reliability Program (PRP) (specific to nuclear weapons)	7	95%: MXS numbers adjusted for RMLV workcenters total 501, while B-2 MXS totals 525. The RMLV requirement is 95% of the B-2 requirement.
MXS/MXM	Maintenance Squadron Supervision provide technical supervision for maintenance production	8		8	95%
MXS/MXMC	Accessories Flight includes Electric/Environmental, Fuels, Pneudraulics, and Egress (omitted)	2		2	Functional workcenter, not adjusted.
MXS/MXMCE	Electrical/Environmental	12		12	Functional workcenter, not adjusted.
MXS/MXMCF	Fuels	20		20	Functional workcenter, not adjusted.
MXS/MXMCP	Pneudraulics includes pneumatics and hydraulics	9		9	Functional workcenter, not adjusted.
MXS/MXMF	Fabrication Flight includes Metals Technology, Non-destructive Inspection, Structural Repair, and Survival Equipment (omitted)	2		2	Functional workcenter, not adjusted.
MXS/MXMFM	Metals Technology	9		9	Functional workcenter, not adjusted.
MXS/MXMFN	Non-destructive Inspection	12		12	Functional workcenter, not adjusted.
MXS/MXMFS	Structural Repair is the largest section because they perform all of the intensive low-observable material maintenance	184		184	Functional workcenter, not adjusted.
MXS/MXMG	Aerospace Ground Equipment flight	99		99	Functional workcenter, not adjusted.
MXS/MXMP	Propulsion Flight includes Jet Engine Intermediate Maintenance, Test Cell, Support Equipment, and Accessory sections	1	107	1	Functional workcenter, not adjusted.
MXS/MXMPJ	Jet Engine Intermediate Maintenance	22	0.220164609	22	Functional workcenter, not adjusted.
MXS/MXMPT	Test Cell includes operational checks, adjustments, and minor repairs	12		12	Functional workcenter, not adjusted.
MXS/MXMPS	Propulsion Support provides parts and tools support	8		8	Functional workcenter, not adjusted.

Workcenter	Responsibility	LCOM Total	Variances not Authorized	Total - Variances	Overhead Adjustments
MXS/MXMT	Maintenance Support Flight includes Inspection and Wheels & Tires	1		1	Functional workcenter, not adjusted.
MXS/MXMTC	Inspection	29		29	Functional workcenter, not adjusted.
MXS/MXMTR	Wheels & Tires	28		28	Functional workcenter, not adjusted.
MXS/MXMV	Avionics, includes test station	36		36	Functional workcenter, not adjusted.
MXS Total		502		501	
MUNS/CC/CCQ	Squadron Commander, Staff, and Orderly Room; the following munitions functions would apply to the second stage/payload for the RMLV	7	-1 no PRP	6	64%: MUNS numbers adjusted for RMLV workcenters total 169, compared to 265 positions for the B-2. RMLV requirements are 64% of B-2 requirements.
MUNS/MXW	Munitions Supervision provides technical oversight of munitions production	3		3	64%
MUNS/MXWCB	Munitions Inspection	3		3	Functional workcenter, not adjusted.
MUNS/MXWCC	Munitions Storage and Handling	17		17	Functional workcenter, not adjusted.
MUNS/MXWK	Munitions Systems Flight includes Munitions Control, CAS (omitted), Plans & Scheduling, and Plans and Mobility (omitted)	2		2	64%
MUNS/MXWKA	Munitions Control provides centralized coordination, planning, and direction	12		12	Functional workcenter, not adjusted.
MUNS/MXWKC	Plans & Scheduling	2		2	Functional workcenter, not adjusted.
MUNS/MXWP	Munitions Production Flight includes Conventional Munitions Maintenance, Precision Guided Munitions (omitted), Handling/Line Delivery, Equipment Maintenance, and Training	2		2	64%
MUNS/MXWPA	Conventional Maintenance assembles, tests, and repairs munitions (as stages will be integrated, tested, possibly undergo minor repairs)	22		22	Functional workcenter, not adjusted.
MUNS/MXWPB	Line Delivery	12		12	Functional workcenter, not adjusted.

Workcenter	Responsibility	LCOM Total	Variances not Authorized	Total - Variances	Overhead Adjustments
MUNS/MXWFD	Munitions Support Equipment is separate from AGE, responsible for all munitions-specific handling and support equipment	5		5	Functional workcenter, not adjusted.
MUNS/MXWPT	Munitions Training	4		4	64%
MUNS/MXWR	Armament Systems Flight focuses on repair and inspection of aircraft and equipment components for loading munitions	17		17	Functional workcenter, not adjusted.
MUNS/MXWSS	Weapons Support performs supply functions	28		28	Functional workcenter, not adjusted.
MUNS/MXWSW	Weapons Maintenance	33		33	Functional workcenter, not adjusted.
MUNS Total		169		168	
AMXS/CC/CCQ	Squadron Commander, Staff, and Orderly Room	9	-2 no PRP	7	50%: AMXS supervision is reduced by half since only one AMU is required for RMLV maintenance.
AMXS/MXA	Maintenance Supervision provides technical supervision for maintenance production	9		9	50%
AMXS/MXAA	Aircraft Maintenance Unit Supervision	19		19	100%: This supervision is specific to the single AMU, whose manpower did not change.
AMXS/MXAAA	Aircraft Section provides first-level maintenance associated with ground handling and servicing	78		78	Functional workcenter, not adjusted.
AMXS/MXAAF	Support Sections ensurex support equipment/supply support is available	18		18	Functional workcenter, not adjusted.
AMXS/MXAAS	Specialists include Engines, Electrics/Environmental, Pneudraulics, and Avionics personnel for troubleshooting and on-aircraft repairs	88		88	Functional workcenter, not adjusted.
AMXS/MXAAW	Weapons loaders, maintainers, and expediters who load munitions onto the aircraft	91		91	Functional workcenter, not adjusted.
AMXS Total		312		310	
MXG Total		1155		1117	

	Shift Factor = 1 (no change)	Shift Factor = 1.5 (three shifts)	Propulsion Low	Propulsion High	TPS Low	TPS High
Workcenter	Total * Overhead Adjustment	Total * Shift Adjustment	1.12 * 2 Shift	1.12 * 3 Shift	1.31 * 2 Shift	1.31 * 3 Shift
MXG/CC	6	9	7	11	8	12
MXG/MXL	11	17	11	17	11	17
MXG/MXQ	23	35	23	35	23	35
MXG Total	40	61	41	63	42	64
MOS/CC/CCQ	5	8	7	11	5	8
MOS/MXOO	2	3	2	3	2	3
MOS/MXOOA	10	15	10	15	10	15
MOS/MXOOC	11	17	11	17	11	17
MOS/MXOOE	5	8	5	8	5	8
MOS/MXOOM	17	26	17	26	17	26
MOS/MXOOP	7	11	7	11	7	11
MOS/MXOP	4	6	4	6	4	6
MOS/MXOR	10	15	35	52	10	15
MOS/MXOT	13	20	13	20	13	20
MOS Total	84	129	111	169	84	129
MXS/CC/CCQ	7	11	9	14	12	19
MXS/MXM	8	12	10	15	14	21
MXS/MXMC	2	3	2	3	2	3
MXS/MXMCE	12	18	12	18	12	18
MXS/MXMCF	20	30	20	30	20	30
MXS/MXMCP	9	14	9	14	9	14
MXS/MXMF	2	3	2	3	2	3
MXS/MXMFM	9	14	9	14	9	14
MXS/MXMFN	12	18	12	18	12	18
MXS/MXMFS	184	276	184	276	523	788
MXS/MXMG	99	149	99	149	99	149
MXS/MXMP	1	2	3	7	1	2
MXS/MXMPJ	22	33	77	115	22	33
MXS/MXMPT	12	18	42	63	12	18
MXS/MXMPS	8	12	28	42	8	12
MXS/MXMT	1	2	1	2	1	2
MXS/MXMTC	29	44	29	44	29	44
MXS/MXMTR	28	42	28	42	28	42
MXS/MXMV	36	54	36	54	36	54
MXS Total	501	755	612	923	851	1284
MUNS/CC/CCQ	4	6	4	6	4	6
MUNS/MXW	2	3	2	3	2	3
MUNS/MXWCB	3	5	3	5	3	5
MUNS/MXWOC	17	26	17	26	17	26
MUNS/MXWK	2	3	2	3	2	3
MUNS/MXWKA	12	18	12	18	12	18
MUNS/MXWKC	2	3	2	3	2	3
MUNS/MXWP	2	3	2	3	2	3
MUNS/MXWPA	22	33	22	33	22	33
MUNS/MXWPB	12	18	12	18	12	18
MUNS/MXWPD	5	8	5	8	5	8
MUNS/MXWPT	3	5	3	5	3	5
MUNS/MXWR	17	26	17	26	17	26
MUNS/MXWSS	28	42	28	42	28	42
MUNS/MXWSW	33	50	33	50	33	50
MUNS Total	164	249	164	249	164	249
AMXS/CC/CCQ	4	6	4	6	4	6
AMXS/MXA	5	8	5	8	5	8
AMXS/MXAA	19	29	19	29	19	29
AMXS/MXAAA	78	117	78	117	78	117
AMXS/MXAAF	18	27	18	27	18	27
AMXS/MXAAS	88	132	88	132	88	132
AMXS/MXAAW	91	137	91	137	91	137
AMXS Total	303	456	303	456	303	456
MXG Total	1092	1650	1231	1860	1444	2182

	Based on Propulsion High, Structural Repair Center			Based on Propulsion Low, Structural Repair Center		
	Complexity Low	Complexity Center	Complexity High	Complexity Low	Complexity Center	Complexity High
Workcenter	1.5	2	2.5	1.5	2	2.5
MXG/CC	20	26	33	14	18	23
MXG/MXL	26	34	43	17	22	28
MXG/MXQ	53	70	88	35	46	58
MXG Total	99	130	164	66	86	109
MOS/CC/CCQ	17	22	28	11	14	18
MOS/MXOO	5	6	8	3	4	5
MOS/MXOOA	23	30	38	15	20	25
MOS/MXOOC	26	34	43	17	22	28
MOS/MXOOE	12	16	20	8	10	13
MOS/MXOOM	39	52	65	26	34	43
MOS/MXOOP	17	22	28	11	14	18
MOS/MXOP	9	12	15	6	8	10
MOS/MXOR	79	105	131	53	70	88
MOS/MXOT	30	40	50	20	26	33
MOS Total	257	339	426	170	222	281
MXS/CC/CCQ	29	38	48	18	24	30
MXS/MXM	30	40	50	21	28	35
MXS/MXMC	5	6	8	3	4	5
MXS/MXMCE	27	36	45	18	24	30
MXS/MXMCF	45	60	75	30	40	50
MXS/MXMCP	21	28	35	14	18	23
MXS/MXMF	5	6	8	3	4	5
MXS/MXMFM	21	28	35	14	18	23
MXS/MXMFN	27	36	45	18	24	30
MXS/MXMFS	828	1104	1380	552	736	920
MXS/MXMG	224	298	373	149	198	248
MXS/MXMP	11	14	18	6	7	9
MXS/MXMPJ	173	231	288	116	154	192
MXS/MXMPT	95	126	157	63	84	105
MXS/MXMPS	63	84	105	42	56	70
MXS/MXMT	3	4	5	2	2	3
MXS/MXMTC	66	88	110	44	58	73
MXS/MXMTR	63	84	105	42	56	70
MXS/MXMV	81	108	135	54	72	90
MXS Total	1817	2419	3025	1209	1607	2011
MUNS/CC/CCQ	9	12	15	6	8	10
MUNS/MXW	5	6	8	3	4	5
MUNS/MXWCB	8	10	13	5	6	8
MUNS/MXWCC	39	52	65	26	34	43
MUNS/MXWK	5	6	8	3	4	5
MUNS/MXWKA	27	36	45	18	24	30
MUNS/MXWKC	5	6	8	3	4	5
MUNS/MXWP	5	6	8	3	4	5
MUNS/MXWPA	50	66	83	33	44	55
MUNS/MXWPB	27	36	45	18	24	30
MUNS/MXWPD	12	16	20	8	10	13
MUNS/MXWPT	8	10	13	5	6	8
MUNS/MXWR	39	52	65	26	34	43
MUNS/MXWSS	63	84	105	42	56	70
MUNS/MXWSW	75	100	125	50	66	83
MUNS Total	377	498	626	249	328	413
AMXS/CC/CCQ	9	12	15	6	8	10
AMXS/MXA	12	16	20	8	10	13
AMXS/MXAA	44	58	73	29	38	48
AMXS/MXAAA	176	234	293	117	156	195
AMXS/MXAAF	41	54	68	27	36	45
AMXS/MXAAS	198	264	330	132	176	220
AMXS/MXAAW	206	274	343	137	182	228
AMXS Total	686	912	1142	458	606	759
MXG Total	3236	4296	5383	2150	2849	3573

	Based on Propulsion High, Structural Repair Center			Based on Propulsion Low, Structural Repair Center		
	Complexity Low	Complexity Center	Complexity High	Complexity Low	Complexity Center	Complexity High
Workcenter	1.5	2	2.5	1.5	2	2.5
MXG/CC	20	26	33	14	18	23
MXG/MXL	26	34	43	17	22	28
MXG/MXQ	53	70	88	35	46	58
MXG Total	99	130	164	66	86	109
MOS/CC/CCQ	17	22	28	11	14	18
MOS/MXOO	5	6	8	3	4	5
MOS/MXOOA	23	30	38	15	20	25
MOS/MXOOC	26	34	43	17	22	28
MOS/MXOOE	12	16	20	8	10	13
MOS/MXOOM	39	52	65	26	34	43
MOS/MXOOP	17	22	28	11	14	18
MOS/MXOP	9	12	15	6	8	10
MOS/MXOR	79	105	131	53	70	88
MOS/MXOT	30	40	50	20	26	33
MOS Total	257	339	426	170	222	281
MXS/CC/CCQ	29	38	48	18	24	30
MXS/MXM	30	40	50	21	28	35
MXS/MXMC	5	6	8	3	4	5
MXS/MXMCE	27	36	45	18	24	30
MXS/MXMCF	45	60	75	30	40	50
MXS/MXMCP	21	28	35	14	18	23
MXS/MXMF	5	6	8	3	4	5
MXS/MXMFM	21	28	35	14	18	23
MXS/MXMFN	27	36	45	18	24	30
MXS/MXMFS	828	1104	1380	552	736	920
MXS/MXMG	224	298	373	149	198	248
MXS/MXMP	11	14	18	6	7	9
MXS/MXMPJ	173	231	288	116	154	192
MXS/MXMPT	95	126	157	63	84	105
MXS/MXMPS	63	84	105	42	56	70
MXS/MXMT	3	4	5	2	2	3
MXS/MXMTC	66	88	110	44	58	73
MXS/MXMTR	63	84	105	42	56	70
MXS/MXMV	81	108	135	54	72	90
MXS Total	1817	2419	3025	1209	1607	2011
MUNS/CC/CCQ	9	12	15	6	8	10
MUNS/MXW	5	6	8	3	4	5
MUNS/MXWCB	8	10	13	5	6	8
MUNS/MXWCC	39	52	65	26	34	43
MUNS/MXWK	5	6	8	3	4	5
MUNS/MXWKA	27	36	45	18	24	30
MUNS/MXWKC	5	6	8	3	4	5
MUNS/MXWP	5	6	8	3	4	5
MUNS/MXWPA	50	66	83	33	44	55
MUNS/MXWPB	27	36	45	18	24	30
MUNS/MXWPD	12	16	20	8	10	13
MUNS/MXWPT	8	10	13	5	6	8
MUNS/MXWR	39	52	65	26	34	43
MUNS/MXWSS	63	84	105	42	56	70
MUNS/MXWSW	75	100	125	50	66	83
MUNS Total	377	498	626	249	328	413
AMXS/CC/CCQ	9	12	15	6	8	10
AMXS/MXA	12	16	20	8	10	13
AMXS/MXAA	44	58	73	29	38	48
AMXS/MXAAA	176	234	293	117	156	195
AMXS/MXAAF	41	54	68	27	36	45
AMXS/MXAAS	198	264	330	132	176	220
AMXS/MXAAW	206	274	343	137	182	228
AMXS Total	686	912	1142	456	606	759
MXG Total	3236	4298	5383	2150	2849	3573

	Based on Propulsion High, Complexity Center						
	Fleet Size	Fleet Size	Fleet Size	Fleet Size	Fleet Size	Fleet Size	Fleet Size
Workcenter	1/16 = .0625	2/16 = .125	3/16 = .1875	4/16 = .25	5/16 = .3125	6/16 = .375	7/16 = .4375
MXG/CC	2	4	5	7	9	10	12
MXG/MXL	3	5	7	9	11	13	15
MXG/MXQ	5	9	14	18	22	27	31
MXG Total	10	18	26	34	42	50	58
MOS/CC/CCQ	2	3	5	6	7	9	10
MOS/MXOO	1	1	2	2	2	3	3
MOS/MXOOA	2	4	6	8	10	12	14
MOS/MXOOC	3	5	7	9	11	13	15
MOS/MXOOE	1	2	3	4	5	6	7
MOS/MXOOM	4	7	10	13	17	20	23
MOS/MXOOP	2	3	5	6	7	9	10
MOS/MXOP	1	2	3	3	4	5	6
MOS/MXOR	7	14	20	27	33	40	46
MOS/MXOT	3	5	8	10	13	15	18
MOS Total	26	46	69	88	109	132	152
MXS/CC/CCQ	3	5	8	10	12	15	17
MXS/MXM	3	5	8	10	13	15	18
MXS/MXMC	1	1	2	2	2	3	3
MXS/MXMCE	3	5	7	9	12	14	16
MXS/MXMCF	4	8	12	15	19	23	27
MXS/MXMCP	2	4	6	7	9	11	13
MXS/MXMF	1	1	2	2	2	3	3
MXS/MXMFM	2	4	6	7	9	11	13
MXS/MXMFN	3	5	7	9	12	14	16
MXS/MXMFS	69	138	207	276	345	414	483
MXS/MXMG	19	38	56	75	94	112	131
MXS/MXMP	1	2	3	4	5	6	7
MXS/MXMPJ	15	29	44	58	73	87	102
MXS/MXMPT	8	16	24	32	40	48	56
MXS/MXMPS	6	11	16	21	27	32	37
MXS/MXMT	1	1	1	1	2	2	2
MXS/MXMTC	6	11	17	22	28	33	39
MXS/MXMTR	6	11	16	21	27	32	37
MXS/MXMV	7	14	21	27	34	41	48
MXS Total	160	309	463	608	765	916	1068
MUNS/CC/CCQ	1	2	3	3	4	5	6
MUNS/MXW	1	1	2	2	2	3	3
MUNS/MXWCB	1	2	2	3	4	4	5
MUNS/MXWCC	4	7	10	13	17	20	23
MUNS/MXWK	1	1	2	2	2	3	3
MUNS/MXWKA	3	5	7	9	12	14	16
MUNS/MXWKC	1	1	2	2	2	3	3
MUNS/MXWP	1	1	2	2	2	3	3
MUNS/MXWPA	5	9	13	17	21	25	29
MUNS/MXWPB	3	5	7	9	12	14	16
MUNS/MXWPD	1	2	3	4	5	6	7
MUNS/MXWPT	1	2	2	3	4	4	5
MUNS/MXWR	4	7	10	13	17	20	23
MUNS/MXWSS	6	11	16	21	27	32	37
MUNS/MXWSW	7	13	19	25	32	38	44
MUNS Total	40	69	100	128	163	194	223
AMXS/CC/CCQ	1	2	3	3	4	5	6
AMXS/MXA	1	2	3	4	5	6	7
AMXS/MXAA	4	8	11	15	19	22	26
AMXS/MXAAA	15	30	44	59	74	88	103
AMXS/MXAAF	4	7	11	14	17	21	24
AMXS/MXAAS	17	33	50	66	83	99	116
AMXS/MXAAW	18	35	52	69	86	103	120
AMXS Total	60	117	174	230	288	344	402
MXG Total	296	559	832	1088	1367	1636	1903

	Based on Propulsion Low, Complexity Center						
Workcenter	Fleet Size 1/16 = .0625	Fleet Size 2/16 = .125	Fleet Size 3/16 = 1875	Fleet Size 4/16 = .25	Fleet Size 5/16 = .3125	Fleet Size 6/16 = 375	Fleet Size 7/16 = .4375
MXG/CC	2	3	4	5	6	7	8
MXG/MXL	2	3	5	6	7	9	10
MXG/MXQ	3	6	9	12	15	18	21
MXG Total	7	12	18	23	28	34	39
MOS/CC/CCQ	1	2	3	4	5	6	7
MOS/MXOO	1	1	1	1	2	2	2
MOS/MXOOA	2	3	4	5	7	8	9
MOS/MXOOC	2	3	5	6	7	9	10
MOS/MXOOE	1	2	2	3	4	4	5
MOS/MXOOM	3	5	7	9	11	13	15
MOS/MXOOP	1	2	3	4	5	6	7
MOS/MXOP	1	1	2	2	3	3	4
MOS/MXOR	5	9	14	18	22	27	31
MOS/MXOT	2	4	5	7	9	10	12
MOS Total	19	32	46	59	75	88	102
MXS/CC/CCQ	2	3	5	6	8	9	11
MXS/MXM	2	4	6	7	9	11	13
MXS/MXMC	1	1	1	1	2	2	2
MXS/MXMCE	2	3	5	6	8	9	11
MXS/MXMCF	3	5	8	10	13	15	18
MXS/MXMCP	2	3	4	5	6	7	8
MXS/MXMF	1	1	1	1	2	2	2
MXS/MXMFM	2	3	4	5	6	7	8
MXS/MXMFN	2	3	5	6	8	9	11
MXS/MXMFS	46	92	138	184	230	276	322
MXS/MXMG	13	25	38	50	62	75	87
MXS/MXMP	1	1	2	2	3	3	4
MXS/MXMPJ	10	20	29	39	49	58	68
MXS/MXMPT	6	11	16	21	27	32	37
MXS/MXMPS	4	7	11	14	18	21	25
MXS/MXMT	1	1	1	1	1	1	1
MXS/MXMTC	4	8	11	15	19	22	26
MXS/MXMTR	4	7	11	14	18	21	25
MXS/MXMV	5	9	14	18	23	27	32
MXS Total	111	207	310	405	512	607	711
MUNS/CC/CCQ	1	1	2	2	3	3	4
MUNS/MXW	1	1	1	1	2	2	2
MUNS/MXWCB	1	1	2	2	2	3	3
MUNS/MXWCC	3	5	7	9	11	13	15
MUNS/MXWK	1	1	1	1	2	2	2
MUNS/MXWKA	2	3	5	6	8	9	11
MUNS/MXWKC	1	1	1	1	2	2	2
MUNS/MXWP	1	1	1	1	2	2	2
MUNS/MXWPA	3	6	9	11	14	17	20
MUNS/MXWPB	2	3	5	6	8	9	11
MUNS/MXWPD	1	2	2	3	4	4	5
MUNS/MXWPT	1	1	2	2	2	3	3
MUNS/MXWR	3	5	7	9	11	13	15
MUNS/MXWSS	4	7	11	14	18	21	25
MUNS/MXWSW	5	9	13	17	21	25	29
MUNS Total	30	47	69	85	110	128	149
AMXS/CC/CCQ	1	1	2	2	3	3	4
AMXS/MXA	1	2	2	3	4	4	5
AMXS/MXAA	3	5	8	10	12	15	17
AMXS/MXAAA	10	20	30	39	49	59	69
AMXS/MXAAF	3	5	7	9	12	14	16
AMXS/MXAAS	11	22	33	44	55	66	77
AMXS/MXAAW	12	23	35	46	57	69	80
AMXS Total	41	78	117	153	192	230	268
MXG Total	208	376	560	725	917	1087	1269

	All High				Three Shifts, High			
	Propulsion High	Structural Repair High	Complexity High	Fleet Size 6	Propulsion High	Structural Repair Low	Complexity Low	Fleet Size 6
Workcenter	1.12 * 3 Shift	2.5	2.5	6/16 = .375	1.12 * 3 Shift	1.5	1.5	6/16 = .375
MXG/CC	11	14	35	14	11	12	18	7
MXG/MXL	17	17	43	17	17	17	26	10
MXG/MXQ	35	35	88	33	35	35	53	20
MXG Total	63	66	166	64	63	64	97	37
MOS/CC/CCQ	11	11	28	11	11	11	17	7
MOS/MXOO	3	3	8	3	3	3	5	2
MOS/MXOOA	15	15	38	15	15	15	23	9
MOS/MXOOC	17	17	43	17	17	17	26	10
MOS/MXOOE	8	8	20	8	8	8	12	5
MOS/MXOOM	26	26	65	25	26	26	39	15
MOS/MXOOP	11	11	28	11	11	11	17	7
MOS/MXOP	6	6	15	6	6	6	9	4
MOS/MXOR	52	52	131	50	52	52	79	30
MOS/MXOT	20	20	50	19	20	20	30	12
MOS Total	169	169	426	165	169	169	257	101
MXS/CC/CCQ	14	21	53	20	14	17	26	10
MXS/MXM	15	22	55	21	15	18	27	11
MXS/MXMC	3	3	8	3	3	3	5	2
MXS/MXMCE	18	18	45	17	18	18	27	11
MXS/MXMCF	30	30	75	29	30	30	45	17
MXS/MXMCP	14	14	35	14	14	14	21	8
MXS/MXMF	3	3	8	3	3	3	5	2
MXS/MXMFM	14	14	35	14	14	14	21	8
MXS/MXMFN	18	18	45	17	18	18	27	11
MXS/MXMFS	276	690	1725	647	276	414	621	233
MXS/MXMG	149	149	373	140	149	149	224	84
MXS/MXMP	7	7	18	7	7	7	11	5
MXS/MXMPJ	115	115	288	108	115	115	173	65
MXS/MXMPT	63	63	157	59	63	63	95	36
MXS/MXMPS	42	42	105	40	42	42	63	24
MXS/MXMT	2	2	5	2	2	2	3	2
MXS/MXMTC	44	44	110	42	44	44	66	25
MXS/MXMTR	42	42	105	40	42	42	63	24
MXS/MXMV	54	54	135	51	54	54	81	31
MXS Total	923	1351	3380	1274	923	1067	1604	609
MUNS/CC/CCQ	6	6	15	6	6	6	9	4
MUNS/MXW	3	3	8	3	3	3	5	2
MUNS/MXWCB	5	5	13	5	5	5	8	3
MUNS/MXWCC	26	26	65	25	26	26	39	15
MUNS/MXWK	3	3	8	3	3	3	5	2
MUNS/MXWKA	18	18	45	17	18	18	27	11
MUNS/MXWKC	3	3	8	3	3	3	5	2
MUNS/MXWP	3	3	8	3	3	3	5	2
MUNS/MXWPA	33	33	83	32	33	33	50	19
MUNS/MXWPB	18	18	45	17	18	18	27	11
MUNS/MXWPD	8	8	20	8	8	8	12	5
MUNS/MXWPT	5	5	13	5	5	5	8	3
MUNS/MXWR	26	26	65	25	26	26	39	15
MUNS/MXWSS	42	42	105	40	42	42	63	24
MUNS/MXWSW	50	50	125	47	50	50	75	29
MUNS Total	249	249	626	239	249	249	377	147
AMXS/CC/CCQ	6	6	15	6	6	6	9	4
AMXS/MXA	8	8	20	8	8	8	12	5
AMXS/MXAA	29	29	73	28	29	29	44	17
AMXS/MXAAA	117	117	293	110	117	117	176	66
AMXS/MXAAF	27	27	68	26	27	27	41	16
AMXS/MXAAS	132	132	330	124	132	132	198	75
AMXS/MXAAW	137	137	343	129	137	137	206	78
AMXS Total	456	456	1142	431	456	456	686	261
MXG Total	1860	2291	5740	2173	1860	2005	3021	1155

Workcenter	All Low Propulsion Low 1.12 * 2 Shift	Structural Repair Low 1.5	Complexity Low 1.5	Fleet Size 6 6/16=.375	Fleet Size 1 1/16 = .0625
MXG/CC	7	12	18	7	2
MXG/MXL	11	11	17	7	2
MXG/MXQ	23	23	35	14	3
MXG Total	41	46	70	28	7
MOS/CC/CCQ	7	7	11	5	1
MOS/MXOO	2	2	3	2	1
MOS/MXOOA	10	10	15	6	1
MOS/MXOOC	11	11	17	7	2
MOS/MXOOE	5	5	8	3	1
MOS/MXOOM	17	17	26	10	2
MOS/MXOOP	7	7	11	5	1
MOS/MXOP	4	4	6	3	1
MOS/MXOR	35	35	53	20	4
MOS/MXOT	13	13	20	8	2
MOS Total	111	111	170	69	16
MXS/CC/CCQ	9	12	18	7	2
MXS/MXM	10	14	21	8	2
MXS/MXMC	2	2	3	2	1
MXS/MXMCE	12	12	18	7	2
MXS/MXMCF	20	20	30	12	2
MXS/MXMCP	9	9	14	6	1
MXS/MXMF	2	2	3	2	1
MXS/MXMFM	9	9	14	6	1
MXS/MXMFN	12	12	18	7	2
MXS/MXMFS	184	368	552	207	35
MXS/MXMG	99	99	149	56	10
MXS/MXMP	3	3	6	3	1
MXS/MXMPJ	77	77	116	44	8
MXS/MXMPT	42	42	63	24	4
MXS/MXMPS	28	28	42	16	3
MXS/MXMT	1	1	2	1	1
MXS/MXMTC	29	29	44	17	3
MXS/MXMTR	28	28	42	16	3
MXS/MXMV	36	36	54	21	4
MXS Total	612	803	1209	462	86
MUNS/CC/CCQ	4	4	6	3	1
MUNS/MXW	2	2	3	2	1
MUNS/MXWCB	3	3	5	2	1
MUNS/MXWCC	17	17	26	10	2
MUNS/MXWK	2	2	3	2	1
MUNS/MXWKA	12	12	18	7	2
MUNS/MXWKC	2	2	3	2	1
MUNS/MXWP	2	2	3	2	1
MUNS/MXWPA	22	22	33	13	3
MUNS/MXWPB	12	12	18	7	2
MUNS/MXWPD	5	5	8	3	1
MUNS/MXWPT	3	3	5	2	1
MUNS/MXWR	17	17	26	10	2
MUNS/MXWSS	28	28	42	16	3
MUNS/MXWSW	33	33	50	19	4
MUNS Total	164	164	249	100	26
AMXS/CC/CCQ	4	4	6	3	1
AMXS/MXA	5	5	8	3	1
AMXS/MXAA	19	19	29	11	2
AMXS/MXAAA	78	78	117	44	8
AMXS/MXAAF	18	18	27	11	2
AMXS/MXAAS	88	88	132	50	9
AMXS/MXAAW	91	91	137	52	9
AMXS Total	303	303	456	174	32
MXG Total	1231	1427	2154	833	167

	Fleet Size 6/16 = .375, Propulsion High, Complexity Varied			Fleet Size 6/16 = .375, Propulsion Low, Complexity Varied		
	Complexity Low	**Complexity Center**	**Complexity High**	**Complexity Low**	**Complexity Center**	**Complexity High**
Workcenter	**1.5**	**2**	**2.5**	**1.5**	**2**	**2.5**
MXG/CC	8	10	13	6	7	9
MXG/MXL	10	13	17	7	9	11
MXG/MXQ	20	27	33	14	18	22
MXG Total	38	50	63	27	34	42
MOS/CC/CCQ	7	9	11	5	6	7
MOS/MXOO	2	3	3	2	2	2
MOS/MXOOA	9	12	15	6	8	10
MOS/MXOOC	10	13	17	7	9	11
MOS/MXOOE	5	6	8	3	4	5
MOS/MXOOM	15	20	25	10	13	17
MOS/MXOOP	7	9	11	5	6	7
MOS/MXOP	4	5	6	3	3	4
MOS/MXOR	30	40	50	20	27	33
MOS/MXOT	12	15	19	8	10	13
MOS Total	101	132	165	69	88	109
MXS/CC/CCQ	11	15	18	7	9	12
MXS/MXM	12	15	19	8	11	14
MXS/MXMC	2	3	3	2	2	2
MXS/MXMCE	11	14	17	7	9	12
MXS/MXMCF	17	23	29	12	15	19
MXS/MXMCP	8	11	14	6	7	9
MXS/MXMF	2	3	3	2	2	2
MXS/MXMFM	8	11	14	6	7	9
MXS/MXMFN	11	14	17	7	9	12
MXS/MXMFS	311	414	518	207	276	346
MXS/MXMG	84	112	140	56	75	93
MXS/MXMP	5	6	7	3	3	4
MXS/MXMPJ	65	87	108	44	58	72
MXS/MXMPT	36	48	59	24	32	40
MXS/MXMPS	24	32	40	16	21	27
MXS/MXMT	2	2	2	1	1	2
MXS/MXMTC	25	33	42	17	22	28
MXS/MXMTR	24	32	40	16	21	27
MXS/MXMV	31	41	51	21	27	34
MXS Total	689	916	1141	462	607	763
MUNS/CC/CCQ	4	5	6	3	3	4
MUNS/MXW	2	3	3	2	2	2
MUNS/MXWCB	3	4	5	2	3	3
MUNS/MXWCC	15	20	25	10	13	17
MUNS/MXWK	2	3	3	2	2	2
MUNS/MXWKA	11	14	17	7	9	12
MUNS/MXWKC	2	3	3	2	2	2
MUNS/MXWP	2	3	3	2	2	2
MUNS/MXWPA	19	25	32	13	17	21
MUNS/MXWPB	11	14	17	7	9	12
MUNS/MXWPD	5	6	8	3	4	5
MUNS/MXWPT	3	4	5	2	3	3
MUNS/MXWR	15	20	25	10	13	17
MUNS/MXWSS	24	32	40	16	21	27
MUNS/MXWSW	29	38	47	19	25	32
MUNS Total	147	194	239	100	128	161
AMXS/CC/CCQ	4	5	6	3	3	4
AMXS/MXA	5	6	8	3	4	5
AMXS/MXAA	17	22	28	11	15	18
AMXS/MXAAA	66	88	110	44	59	74
AMXS/MXAAF	16	21	26	11	14	17
AMXS/MXAAS	75	99	124	50	66	83
AMXS/MXAAW	78	103	129	52	69	86
AMXS Total	261	344	431	174	230	287
MXG Total	1236	1636	2039	832	1087	1362

Appendix G. AFMS Excerpts

BY ORDER OF THE SECRETARY OF THE AIR FORCE

AFMS 41A0
30 April 2003

Manpower Standard

★BASE SUPPLY

NOTICE: This publication is available electronically on the AFMIA WWW site at: http://www.afmia.randolph.af.mil/afms/index.htm. If you lack access, contact AFMRUS/RUQ at DSN 487-2479 or commercial (210) 652-2479, extension 3044.

OPR: AFMRDS/RDB (SMSgt Zabel)
Supersedes AFMS 41A0, 13 June 1997

Certified by: AFMRDS/CC (Lt Col Douglas Carroll)
Pages: 52
Distribution: F

This Air Force Manpower Standard (AFMS) quantifies the manpower required to accomplish the tasks described in the process oriented description (POD) for varying levels of workload. The regional base supply function provides supplies and equipment, when needed, to meet worldwide challenges. This function is responsible for requisition, receipt, storage, issue, and inventory of all supplies and equipment. This AFMS provides manpower needed to support all regional base supply squadrons operating under the regionalized concept, reporting data to a command Regional Supply Squadron (RSS) during peacetime. This AFMS does not apply to Major Command (MAJCOM) RSSs. It does not apply to any base supply function that does not fall under the regionalized concept. It does not apply to satellite operations, the Air National Guard, the Air Force Reserve, and Air Logistics Centers. This AFMS does not apply to squadrons that have been cost compared (OMB Circular A-76, *Performance of Commercial Activities*) or are undergoing cost comparison. It also does not apply to bases that have accomplished local reengineering in lieu of outsourcing. Bases should develop negative variances to account for processes not performed or performed by contract and positive variances for processes performed but not included in the AFMS. AFMAN 23-110, *USAF Supply Manual,* contains United States Air Force (USAF) policy and procedural guidance for the regional base supply function. This AFMS has been developed in accordance with policy and guidance from AFI 38-201, *Determining Manpower Requirements*, and AFMAN 38-208, *Air Force Management Engineering Program (MEP)*. Send comments and suggested improvements on AF Form 847, **Recommendation for Change of Publication,** through channels, to AFMRDS/RDB, 550 E. Street East, Randolph AFB, TX, 78150-4451. See **Attachment 1** for a glossary of references and supporting information.

SUMMARY OF REVISIONS

This standard is substantially revised and must be completely reviewed. All processes and variances for this function were reviewed and reengineered in accordance with FY00-05, *Annual Planning and Programming Guidance (APPG)*. Major changes

affecting this AFMS are a result of categorizing bases as regional and non-regional bases. Regional bases are bases that have been regionalized under the RSS) and reflect lowered workload levels as a result of divesting, in whole or part, six major processes (Mission Capability (MICAP), Stock Control, Funds Management, Records Maintenance, Equipment Management, and Computer Operations). Non-regional bases are bases that are not supported by an RSS. An equation could only be developed for the regionalized bases. Bases classified as regional utilize the workload factor (WLF) of average monthly transactions. The PODs for Management and Systems function, Material Storage and Distribution, Material Management function, and Combat Operations Support function are now process aligned rather than functionally aligned. By combining function specific categories of work by processes, it enabled a more efficient manner of measurement and provided the functional community with ease of identifying key processes. Approximately 90 percent of the previously identified variances were incorporated into the POD. Also incorporated into the POD were career field-wide initiatives. Those initiatives are the implementation of sample inventories and decentralized inventory processes, utilization of International Merchant Purchase Authorization Card (IMPAC) for local purchases, implementation of Standard Asset Tracking System (SATS), implementation of web-based technologies for report generation and distribution, automation of the Stock Number Directory, implementation of the Mobility Automated Inventory Tracking System (MAITS) and Mobility Inventory Control Accounting System (MICAS), elimination of consumables from Mobility Readiness Spares Package (MRSP), decentralization of Bench Stock and Inspection processes, closing of Base Service Stores, moving of Pick-up and Delivery function to transportation, reduction of supply flights from five to three, implementation of HAZMART concept, establishment of One Stop Shop concept, and implementation of Phase 1 of Pinpoint Delivery concept.

Page

1. Standard Data.

1.1. Approval Date. 30 April 2003.

1.2. Man-hour Data Source. Per accomplishment times (PAT) were obtained using operational audit. Frequencies (FREQ) were obtained by using technical estimates and historical data. Indirect man-hours were added to the equations during development. No application of the Standard Indirect Allowed Man-hours is required as a result.

1.3. Manpower/Man-hour Equations.

1.3.1. Flight Management. Y=2 (Constant Manpower) for all bases per flight (see flight definition in **Attachment 1**).

1.3.2. Flight Administration. Y=1 (Constant Manpower) for all bases per flight (see flight definition in **Attachment 1**).

1.3.3. Funds Management. Y= 1 (Constant Manpower) for all bases per squadron.

1.3.4. After-hours Support. Determine the number of flying squadrons supported by the after-hours operation. Only one after-hours operation is allowed for each base unless that base supports flying units geographically separate from the main installation. If more than one is valid, a variance should be submitted. Next, determine the normal shift operation for the regional base supply after-hours function based on historical management data. The fractional manpower credited in **Table 1** below is intended to compensate for required shift operations, not to cover the measured workload included in the equation in paragraph **1.3.5**.

Table 1. Supply After-hours Support Matrix

SUPPLY AFTER-HOURS SUPPORT MATRIX		
Number of Flying Squadrons	**Swing Shift Operation Only**	**Swing and Midshift Operations**
1	1.089	2.177
2	2.177	2.722
3	2.722	3.267
4	3.267	3.81
5 or more	3.81	4.355

1.3.5. **Base Supply Man-hour Equation:** Y=.8529X

1.4. Workload Factor (WLF).

1.4.1. X

1.4.1.1. Title. Average Monthly Transactions.

1.4.1.2. Definition. The average total number of transactions from the Consolidated Transaction History (CTH) records under Transaction Identification Codes (TRICs) DOR, DUO, FCS, ISU, REC, and TIN. This data is retail, not wholesale. For standardization purposes, this data will be obtained from the Air Force Logistics Management Agency (AFLMA/LGS). AFLMA will be the only source for this workload factor. Two POCs are listed below.

1.4.1.2.1. AFLMA/LGY, DSN 596-4524.

1.4.1.2.2. AFLMA/LGS, DSN 596-4165.

1.4.1.3. Source. CTH records obtained from AFLMA as specified in paragraph **1.4.1.2**.

1.5. Points of Contact.

1.5.1. Functional Representative. CMSgt Paul Schroder, USAF/ILSP.

1.5.2. AFMIA Representatives. SMSgt Nathaniel Zabel, MSgt Kevin Williams, TSgt Desiree Morrison, and SSgt Gerald Torrey, AFMRDS/RDB.

2. Application Instructions.–

2.1. Step 1. Add 2 fixed (Y=2) flight supervision per authorized and approved flight.

2.2. Step 2. Add 1 fixed (Y=1) flight administration per authorized and approved flight.

2.3. Step 3. Add 1 fixed (Y=1) funds management once for the squadron.

2.4. Step 4. Use **Table 1, Supply After-hours Support Matrix,** to determine the number of flying squadrons supported by the after-hours operation. Next, determine the normal shift operation for the regional base supply after-hours function based on historical management data. The result is the fractional manpower to be added.

2.5. Step 5. Determine the average monthly number of transactions by summing the total from the AFLMA provided CTH record listing and then dividing by the number of months data was obtained. Use the most recent 12 months of peacetime data, excluding months that are not representative. If 12 months are not available, use at least 6 months of representative data.

2.6. Step 6. Using the man-hour equation in paragraph **1.3.5**, substitute the average monthly number of transactions for X and compute the man-hours.

2.7. Step 7. See **Attachment 4** to determine the applicable variance man-hours for your base. Add/subtract the resulting man-hours to the core equation in paragraph **2.6.**

2.8. Step 8. Divide the computed man-hours in paragraph **2.7.** by the applicable man-hour availability factor (MAF) times the overload factor to determine the fractional manpower.

2.9. Step 9. Add the fixed manpower from paragraphs **2.1.** through **2.4.** to the result in paragraph **2.8.**

2.10. Step 10. Exercise Participation Credit Equation. Count only MAJCOM or higher directed exercises that meet the requirements listed in AFMAN 38-208, Volume 1., paragraphs **3.27.6.3.3.** through **3.27.6.5.** for the most recent 24 months of exercise data available. The most important criteria is personnel must be on orders for credit to be given. **Table 2** is provided from AFMAN 38-208, Volume 1. Use the table to compute man-hours and then divide that result by the MAF times the overload factor to determine fractional manpower.

Table 2. Computation of Man-Hours For Exercise Participation.

S T E P	A Action	B Example
1	Identify the work center and base for which the exercise participation man-hours are to be calculated.	WORK CENTER FAC: XXXX WORK CENTER BASE: SMITH AFB
2	Specify the number of months and time frame from which the work center's exercise participation data is obtained.	24 months (Jan 92 - Dec 93)
3	Identify the names of the exercises in which work center personnel participated during the time frame specified in Step 2.	EXERCISE 92-1 EXERCISE 92-2 EXERCISE 92-3 ETC.
4	For each exercise, identify the different periods of time (in calendar days) for which work center personnel participated in the exercise.	Exercise Name — Number of Calendar Days EXERCISE 92-1 — 30 15 EXERCISE 92-3 — 15 ETC.

5	For each period of time identified in Step 4, specify how many work center personnel participated.	For Exercise 92-1 Number of Calendar Days — Number of Personnel 30 — 2 15 — 2
6	Compute the man-hours for each time period in the exercise. Multiply the calendar days of each time period by the number of people who participated for that time (found in Step 5) by the numerical constant of 10.29 (see note).	For Exercise 92-1 (30) (2) (10.29) = 617.40 man-hours (15) (2) (10.29) = 308.70 man-hours
7	Multiply the man-hours from Step 6 by a MAF constant. The MAF constant is the ratio of the applicable peacetime MAF times the overload factor (151.5 x 1.077 for CONUS & overseas) to the military wartime surge MAF (309). It converts a wartime surge man-hour value to a peacetime equivalent value. The MAF constant is 0.53.	Smith AFB is a CONUS base. Therefore, for Exercise 92-1, the following will be multiplied. (617.40) (.53) = 327.22 (308.70) (.53) = 163.61
8	Sum the man-hour values computed in Step 7 for all exercises in the study time frame.	Total Exercise Man-hours = 8000.57
9	Compute the average monthly man-hours for a work center's exercise participation by dividing the man-hour total found in Step 8 by the number of months for which exercise data is reported (Step 2).	$\frac{8000.57}{24} = 333.38$
10	Divide the calculated monthly man-hours found in Step 9 by the MAF times the overload factor to obtain fractional manpower.	$\frac{333.38}{163.2} = 2.04$

NOTE. The constant used in Step 6 is the result of the monthly assigned days for wartime surge divided by the average monthly calendar days multiplied by the wartime surge man-hours per person.

$$\frac{(26.09)\ (12)}{30.44} = 10.29$$

2.11. Step 11. Deployment Participation Credit Equation. Count only MAJCOM or higher directed deployments (including Air Expeditionary Force (AEF) taskings) for the most recent 24 months of available data. **Table 3** is provided to assist you in calculating fractional manpower credit.

Table 3. Computation of Support Function Man-hours for Contingency Participation.

Step	A Action	B Example
1	Identify the functional account code, installation, and organization PAS code for which the contingency participation man-hours are to be calculated.	FAC: 43C1 Installation: Smith AFB Organization PAS Code: FXXX
2	Specify the number of months and time frame from which the function's contingency participation data is obtained. Time frame must be at least 6 months; however, 24 months is preferable.	24 Months (Oct 00 – Sep 02)

3	Identify the names of the contingencies in which function personnel participated during the time frame specified in Step 2 and the associated periods of deployment. **NOTE: Do not include contingencies where workload reduced at the home station as a result of deployment actions. For example, if a supply function deploys personnel with their Mobag commitment, the workload went with them, reducing home station workload. No contingency credit should be given.**	<u>Contingency</u> / <u>Deployment Dates</u> Contingency 00-6 Nov – Dec 00 Contingency 01-1 Mar – May 01 Classified Contingency Sep – Nov 01
4	For each contingency identified in Step 3, specify the total number of deployed man-days (one man-day equals one person deployed for one day). **Do not include any deployed man-days for personnel deployed with workload from home station. For example, for Fire Protection Function, do not include any deployed man-days for personnel deployed along with, and assigned to, their own home station's fire protection vehicles.**	<u>Contingency</u> / <u>Deployed Man-days</u> Contingency 00-6 120 Contingency 01-1 245 Classified Contingency 193
5	Compute the man-hours lost from the function. Multiply the deployed man-days from Step 4 by the daily man-hour constant of 5.360. This constant reflects the military peacetime MAF times the overload factor (151.5 X 1.077) divided by the average monthly calendar days (30.44). For Fire Protection Function only, the daily man-hour constant is 9.297 (283/30.44).	<u>Contingency</u> / <u>Man-hours</u> Contingency 00-6 (120) (5.360) = 643.20 Contingency 01-1 (245) (5.360) = 1,313.20 Classified Contingency (193) (5.360) = 1,034.48
6	Sum all of the contingency man-hour values computed in Step 5.	Total Contingency Man-hours = 2,990.88
7	Compute the average monthly man-hours for a function's contingency participation by dividing the man-hour total found in Step 6 by the number of months for which data is reported (Step 2).	$\frac{2,990.88}{24} = 124.62$
8	Divide the calculated monthly man-hours found in Step 7 by 163.2 to obtain fractional manpower.	$\frac{124.62}{163.2} = .7636$

2.12. Step 12. Add the results from paragraphs **2.10.** and **2.11.** to the result in paragraph **2.9.** to obtain total fractional manpower. Round up to the next whole manpower value. Convert the manpower into man-hours and use AFI 38-201, *Determining Manpower Requirements*, Table **2.2.** to guide application procedures. Refer to **Attachment 3**, Manpower Table for skill and grade.

2.13. Step 13. Apply AFMS XXX0, *Function Commander's Support Staff,* to determine commander, section commander, first sergeant, and information management and personnel requirements using the manpower result from paragraph **2.12.** plus the manpower result obtained from application of AFMS 41D1, ***Fuels Management***. .

3. Statement of Conditions. This function's normal hours of operation are 8 hours a day, 5 days a week. Exception: Computer Operations and After-hours support are 24-

hour a day, 7-day-a-week operations. No environmental or physiological factors were identified that had a manpower impact.

WILLIAM C. BENNETT, JR., Colonel, USAF
Commander, Air Force Manpower and
Innovation Agency

STANDARD MANPOWER TABLE											
WORK CENTER/FAC Base Supply Function/41A0			APPLICABILITY MAN-HOUR RANGE Extrapolation Limits Not Used								
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Supply	021S3	CPT	1	1	1	1	1	1	1	1	1
Supply	021S3	LT							1	1	1
Supply Management Supt	2S0XX	CMS									
Supply Management Supt	2S0XX	SMS	1	1	1	1	1	1	1	1	1
Supply Mgt Craftsman	2S07X	MSG	2	2	2	2	2	2	2	2	2
Supply Mgt Craftsman	2S07X	TSG	3	3	3	3	3	4	4	4	4
Supply Mgt Journeyman	2S05X	SSG	9	10	10	10	11	11	11	11	11
Supply Mgt Journeyman	2S05X	SRA	13	13	13	14	14	14	14	15	15
Supply Mgt Apprentice	2S03X	A1C	10	10	11	11	11	11	11	11	12
NOTE: 2S0 requirements may be comprised of 2S0X1, 2S0X2, or 3A0X1 as determined by local supply managers											
TOTAL			39	40	41	42	43	44	45	46	47
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Supply	021S3	CPT	1	1	1	1	1	1	1	1	1
Supply	021S3	LT	1	1	1	1	1	1	1	1	1
Supply Management Supt	2S0XX	CMS					1	1	1	1	1
Supply Management Supt	2S0XX	SMS	1	1	1	1	1	1	1	1	1
Supply Mgt Craftsman	2S07X	MSG	2	2	2	3	3	3	3	3	4
Supply Mgt Craftsman	2S07X	TSG	4	5	5	5	5	5	6	6	6
Supply Mgt Journeyman	2S05X	SSG	12	12	12	12	12	13	13	13	13
Supply Mgt Journeyman	2S05X	SRA	15	15	15	15	15	15	15	16	16
Supply Mgt Apprentice	2S03X	A1C	12	12	13	13	13	13	13	13	13
NOTE: 2S0 requirements may be comprised of 2S0X1, 2S0X2, or 3A0X1 as determined by local supply managers											
TOTAL			48	49	50	51	52	53	54	55	56

AF Form 1113, JUN 91 (COMPUTER GENERATED). PREVIOUS EDITION IS OBSOLETE.

A4.14.1. Definition. Additional man-hours required to support supply squadron management of unique TRIC codes.

A4.14.2. Impact and Applicability. Davis Monthan AFB, +187.5 man-hour requirements.

A4.15. Title. Positive Mission Variance for Pinpoint Delivery.

A4.15.1. Definition. Additional man-hours required to provide mission-critical pinpoint delivery capability. Reflects the additional requirement to track due-outs and parts movement.

A4.15.2. Impact and Applicability. Whiteman AFB, +98.54 man-hour requirements.

A4.16. Title. Positive Mission Variance for Low Observable Contract Support.

A4.16.1. Definition. Additional man-hours required to coordinate and support the required low observable contract.

A4.16.2. Impact and Applicability. Whiteman AFB, +330.38 man-hour requirements.

A4.17. Title. Positive Mission Variance for Individual Equipment Element (IEE) Maintained within Base Supply.

A4.17.1. Definition. Additional man-hours required to maintain IEE when it is managed with active duty members assigned to a different work center. IEE is the single manager and stockage point for all Federal Supply Class "84" items allowed excluding organizational and mobility Equipment Authorized In-use Detail (EAID) items.

A4.17.2. Impact and Applicability. Lajes Field AB, +59.97 man-hour requirements.

A4.18. Title. Positive Mission Variance for Geographically Separated Parts Store for Unmanned Aerial Vehicle (UAV).

A4.18.1. Definition. Additional man-hours required to maintain a Predator Supply Support requirement that operates 24/7. This function has the responsibility for requisition, receipt, storage, issue, and inventory of all supplies and equipment supporting the Predator program. The parts store is located approximately 50 miles north of the base supply squadron located on Nellis AFB and is manned by Nellis personnel. This variance covers the management of consumable items for a deployable benchstock.

A4.18.2. Impact and Applicability. Nellis AFB, +815.85 man-hour requirements.

Attachment 5

PROCESS ANALYSIS SUMMARY

Table A5.1. PROCESS ANALYSIS SUMMARY, BASE SUPPLY

PROCESS TITLE (In Priority Order)	**PROCESS TIME** (Avg Mthly MHRS)
1. Management	979.32
2. Administrative Support	489.60
3. Materiel Receipt	635.48
4. Materiel Storage	5003.07
5. Materiel Request	1560.36
6. Materiel from Stock	1382.61
7. Stock Control Operation	1681.66
8. Data Management	1526.62
9. Quality Assurance and Quality Control	2732.75
10. Guidance Development	113.98
11. Customer Assistance	574.67
12. Customer Training	93.49
13. Information Systems Management	789.54
14. War Readiness and Mobility	1433.01
15. Materiel Transportation	598.28
16. Funds Management	163.20
17. Travel	385.84

NOTE: The processes are listed in order of decreasing priority.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

AFMS 41D1
30 April 2003

Manpower Standard

★*FUELS MANAGEMENT*

NOTICE: This publication is available electronically on the AFMIA WWW site at: http://www.afmia.randolph.af.mil/afms/index.htm. If you lack access, contact AFMRUS/RUQ at DSN 487-2479 or commercial (210) 652-2479, extension 3044.

OPR: AFMRDS/RDB (SMSgt Zabel)
Supersedes AFMS 41D1, 3 May 1996

Certified by: AFMRDS/CC
(Lt Col Douglas Carroll)
Pages: 38
Distribution: F

This Air Force Manpower Standard (AFMS) quantifies the manpower required to accomplish the tasks described in the Process Oriented Description (POD) for varying levels of workload. The mission of the Fuels Management flight is to manage, store, and distribute all petroleum products, oils, lubricants, missile propellants, and cryogenics products. This AFMS defines the manpower allowed to support a Fuels Management Flight at Air Mobility Command, Air Combat Command, US Air Forces Europe (except Incirlik AB due to unique operations environment), Air Force Materiel Command, Air Education and Training Command, Air Force Special Operations Command, and Pacific Air Forces bases (excluding Hickam AFB and Andersen AFB due to reengineering in lieu of outsourcing). It does not apply to Air Force Space Command, Air National Guard, and Air Force Reserve bases. This attachment does not apply to flights that have been cost compared (OMB Circular A-76, *Performance of Commercial Activities*). It applies to peacetime operations only. AFI 23-201, *Fuels Management,* contains United States Air Force (USAF) policy and procedural guidance for the Fuels Management Flight. This standard has been developed in accordance with policy and guidance from AFI 38-201, *Determining Manpower Requirements*, and AFMAN 38-208, *Air Force Management Engineering Program (MEP)*. Send comments and suggested improvements on AF Form 847, **Recommendation for Change Publication**, through channels, to AFMRDS/RDB, 550 E. Street East, Randolph AFB, TX 78150-4451. A glossary of references and supporting information is at **Attachment 1.**

SUMMARY OF REVISIONS

This standard is substantially revised and must be completely reviewed. All processes and variances for this function were reviewed and reengineered in accordance with FY00-05, *Annual Planning and Programming Guidance (APPG)*. This AFMS supercedes AFMS 41D1, 3 May 96. The result is a process-based POD to replace the previous functionally aligned POD. Fixed positions for operation of the Resource Control Center (RCC) have been validated at 14 authorizations for each location. The RCC includes the fuels accounting and administration processes and an expeditor. Storage and Distribution have been separated into distinct processes. The receiving portion of the POD receives a new matrix to provide essential manning for critical operations. Variances A3.1., A3.2., and A3.3. used to adjust objective wing core composition have been eliminated. Four fixed positions for Checkpoint Operation have been added. Travel has been isolated as a separate process in order to reduce variability among core workload processes. Peak workload man-hours have been developed to adjust measured man-hours for manning based on operational demands of the flightline. The equation in the manuscript, paragraph 1.3.8., was revised using new workload factors and other equations have been eliminated. In addition, man-hour credit for non-Air Expeditionary Force (AEF) contingency deployments is included in the standard. AEF authorizations have already been placed at specific bases.

Page

1. Standard Data.

1.1. Approval Date: 30 April 2003.

1.2. Man-hour Data Source. Per accomplishment times (PAT) were collected via operational audit and validated with good operator timing for all processes except management, administration, and the RCC. These exceptions were given validated historical fixed manning. Frequencies were obtained primarily from the Fuels Automated System (FAS). The remaining frequencies were obtained through historical documents and technical estimates as a last resort. A staffing pattern matrix was developed for Fuels Product Receiving. Quality Control and Inspection were measured to validate fixed manning of 4 positions. Indirect man-hours were added to the equations during development. No application of the Standard Indirect Allowed Man-hours is required as a result.

1.3. Manpower Man-Hour Equations.

1.3.1. Fuels Management. Y=2 (Constant Manpower).
1.3.2. Fuels Administration. Y=1 (Constant Manpower).

1.3.3. Resource Control Center. Y=14 (Constant Manpower).

1.3.4. Checkpoint Operation. Y=4 (Constant Manpower).

1.3.5. Quality Control and Inspection. Y=4 (Constant Manpower).

1.3.6. Fuels Flight Support. Y=2 (Constant Manpower).

1.3.7. Fuels Receiving Personnel. Determine what the normal shift operation for the receiving section historically has run. Next, determine the appropriate mode of delivery for all gallons of fuel product received. Mixed delivery modes would apply if the fuels flight uses two modes of delivery (for example, pipeline and truck delivery modes). Locations refer to fuel flights that receive fuel products at multiple locations simultaneously. Use **Table 1** matrix of fractional manpower to determine personnel required for critical fuels storage operations based on normal shift operations and mode of receipt.

Table 1. Fuels Receiving Matrix

FUELS RECEIVING MATRIX			
MODE OF RECEIPT	**One Shift**	**Two Shift**	**Three Shift**
Pipeline (> 96% of total Receipts)	1.492	2.985	4.477
Truck or Rail Car Only	2.132	4.264	5.33
Mixed Receipt Modes/Locations	3.624	6.609	7.675

1.3.8. Fuels Management Man-hour Equation:
$Y=948.758+(1053.6149X_1)+(97.5441X_2)$.

1.3.9. Workload Factors (WLF).

1.3.9.1. X_1.

1.3.9.1.1. Title. Gallons of Fuel Product Received.

1.3.9.1.2. Definition. The monthly average total gallons (in millions) of all fuel product received by the fuels management flight regardless of type or delivery mode. To obtain this data, have the fuels technicians run a query in the FAS Accounting Module for all grades of product received. Add to that number the total gallons of product received that are documented in the daily document folders (i.e.,Liquid Oxygen (LOX), Liquid Nitrogen (LIN), and Deicing products).

1.3.9.1.3. Source. Accounting Module in the FAS and/or daily document folders. Include all the receipts annotated in the daily document control folders that are not captured in the FAS module.

1.3.9.2. X_2.

1.3.9.2.1. Title. Fuels Product Transfers.

1.3.9.2.2. Definition. The monthly average number of all fuels transfers. Count the number of transfers (aviation, ground, and cryogenics) from the FAS Log sheet, controllers log, AF Form 834, **Record of Fuels Transfers**, AF Form 1233, **Bulk Storage Summary,** or locally developed equivalent. A transfer that fills up multiple tanks at one pumphouse is considered one transfer. Anything that involves the issue and/or receipt of fuel product is not considered a transfer. Truck fills are not considered transfers. Truck-to-truck fills are not considered transfers. Filling trucks for delivery to other locations are not considered transfers. Take a monthly average of all transfers made using the most recent 12 months of peacetime data, excluding months that are atypical due to deployments or runway closures. If 12 months is not available, use at least six months of typical data. If documentation is duplicated on several sources, be sure to only count the most reliable source to avoid double counting.

1.3.9.2.3. Source. Log sheet Module in FAS, controllers log, AF Form 834, AF Form 1233, or locally developed equivalent.

1.4. Points of Contact.

1.4.1. Functional Representative. CMSgt David A. Eklund, HQ AETC/LGSF.

1.4.2. AFMIA Representatives. SMSgt Nathaniel M. Zabel & TSgt Gerald E. Torrey, AFMRDS/RDB.

2. Application Instructions.

2.1. Critical Fuels Receiving Personnel Matrix.

2.1.1. Step 1. Count the number of normal storage area shifts that actively receive fuel product. If an area is manned 24-hours a day, but only receives fuel product during two shifts, then you ignore the third shift. Do not count atypical or sporadic shift operations.

2.1.2. Step 2. Determine the type of delivery mode actively used in the fuels management flight. Mixed delivery mode includes any fuels management flight that receives fuel product by more than one type of delivery mode, with the exception of those bases that receive more than 96 percent of product by pipeline. Locations on the matrix (**Table 1**) refer to fuel flights that receive fuel products at multiple locations simultaneously. If a base receives fuel product at more than one location, but the mode is the same, it is still counted as a mixed delivery mode.

2.1.3. Step 3. Use the number of shifts determined from paragraph **2.1.1**, and type of delivery mode determined from paragraph **2.1.2**, and use matrix (**Table 1**) to determine fractional manpower to be applied.

2.2. Fuels Management Manpower Equation, paragraph **1.3.8.**

2.2.1. Step 1. Use the Accounting Module of FAS and daily document folders to determine total gallons of fuel product received. Take a monthly average of all products received using the most recent 12 months of peacetime data, excluding months that are atypical due to deployments, runway closures, and fuel storage tank servicing periods. If 12 months is not available, use at least 6 months of typical data.

2.2.2. Step 2. Divide the result from paragraph **2.2.1** by 1,000,000.

2.2.3. Step 3. Insert the value from paragraph **2.2.2** into the X_1 value of the equation in paragraph **1.3.8.**

2.2.4. Step 4. Use the Log Sheet Module of the Fuels Automated System (FAS), controllers log, AF Form 834, AF Form 1233, and/or locally developed equivalent to determine the fuels transfers (aviation, ground, and cryogenics). Do not double count.

2.2.5. Step 5. Insert the value from paragraph **2.2.4** into the X_2 value of the equation in paragraph **1.3.8.**

2.2.6. Step 6. Calculate the result for the equation in paragraph **1.3.8** using the workload factors. Divide the resulting man-hours by the applicable Man-hour Availability Factor (MAF). This is the fractional manpower for core workload.

2.3. Adding Fixed Manpower to Fractional Manpower results.

2.3.1. Step 1. Add the results from paragraphs **2.1.3**, and **2.2.6.**

2.3.2. Step 2. Add 2 fixed (Y=2) manpower for the overhead management of the fuels flight to the result in paragraph **2.3.1.**

2.3.3. Step 3. Add 1 fixed (Y=1) manpower for the overhead administration of the fuels flight to the result in paragraph **2.3.2.**

2.3.4. Step 4. Add 14 fixed (Y=14) manpower for the RCC to the result in paragraph **2.3.3.** The fixed manpower is 14 for all locations since each require 24 hours a day, 7-days a week operations.

2.3.5. Step 5. Add 4 fixed (Y=4) manpower for the Checkpoint Operation process to the result in paragraph **2.3.4.**

2.3.6. Step 6. Add 4 fixed (Y=4) manpower for the Quality Control and Inspection process to the result in paragraph **2.3.5.**

2.3.7. Step 7. Add 2 fixed (Y=2) manpower for the Fuels Flight Support process to the result in paragraph **2.3.6.**

2.3.8. Step 8. See **Attachment 4** to determine the applicable variance man-hours for your base. Sum the applicable man-hours for your base and convert this man-hour total to fractional manpower dividing by the appropriate MAF.

2.3.9. Step 9. Add or subtract the fractional manpower obtained from all applicable variances in paragraph **2.3.8** to the fractional manpower obtained in paragraph **2.3.7.**

2.3.10. Step 10. Exercise Participation Credit Equation. Count only Major Command (MAJCOM) or higher directed exercises that meet the requirements listed in AFMAN 38-208, Vol. 1., paragraphs **3.27.6.3.3** through **3.27.6.5**, for the most recent 24 months of exercise data available. The most important criteria is that personnel must be on orders for credit to be given. **Table 2** is provided from AFMAN 38-208, Vol. 1. Use the table to compute man-hours and then divide that result by the MAF times the overload factor to determine fraction manpower.

Table 2. Computation of Man-Hours for Exercise Participation.

STEP	A Action	B Example
1	Identify the work center and base for which the exercise participation man-hours are to be calculated.	WORK CENTER FAC: XXXX WORK CENTER LOCATON: SMITH AFB
2	Specify the number of months and time frame from which the work center's exercise participation data is obtained.	24 months (Jan 92 - Dec 93)
3	Identify the names of the exercises in which work center personnel participated during the time frame specified in Step 2.	EXERCISE 92-1 EXERCISE 92-2 EXERCISE 92-3 ETC.
4	For each exercise, identify the different periods of time (in calendar days) for which work center personnel participated in the exercise.	Exercise Name Number of Calendar Days EXERCISE 92-1 30 15 EXERCISE 92-3 15 ETC
5	For each period of time identified in Step 4, specify how many work center personnel participated.	For Exercise 92-1 Number of Calendar Days / Number of Personnel 30 2 30 2
6	Compute the man-hours for each time period in the exercise. Multiply the calendar days of each time period by the number of people who participated for that time (found in Step 5) by the numerical constant of 10.29 (see note).	For Exercise 92-1 (30)(2)(10.29) = 617.40 man-hours (15)(2)(10.29) = 308.70 man-hours

STEP	A Action	B Example
7	Multiply the man-hours from Step 6 by a MAF constant. The MAF constant is the ratio of the applicable peacetime MAF times the overload factor (151.5 x 1.077 for Continental United States [CONUS] & overseas) to the military wartime surge MAF (309). It converts a wartime surge man-hour value to a peacetime equivalent value. The MAF constant is 0.53.	Smith AFB is a CONUS base. Therefore, for Exercise 92-1, the following will be multiplied: (617.40)(.53) = 327.22 (308.70)(.53) = 163.61
8	Sum the man-hour values computed in Step 7 for all exercises in the study time frame.	Total Exercise Man-hours = 8000.57
9	Compute the average monthly man-hours for a work center's exercise participation by dividing the man-hour total found in Step 8 by the number of months for which exercise data is reported (Step 2).	$\frac{8000.57}{24} = 333.38$
10	Divide the calculated monthly man-hours found in Step 9 by the MAF times the overload factor to obtain fractional manpower.	$\frac{333.38}{163.2} = 2.0$
NOTE: The constant used in Step 6 is the result of the monthly assigned days for wartime surge divided by the average monthly calendar days multiplied by the wartime surge man-hours per person. $\frac{(26.09)(12)}{30.44} = 10.29$		

2.3.11. Step 11. Deployment Participation Credit Equation. Count Only MAJCOM or higher directed non-AEF deployments for the most recent 24 months of available data. **Table 3** is provided to assist you in calculating fractional manpower credit.

Table 3. Computation of Support Function Man-hours for Contingency Participation.

STEP	A Action	B Example
1	Identify the functional account code, installation, and organization PAS code for which the contingency participation man-hours are to be calculated.	FAC: 43C1 Installation: Smith AFB Organization PAS Code: FXXX
2	Specify the number of months and time frame from which the function's contingency participation data is obtained. Time frame must be at least 6 months; however, 24 months is preferable.	24 months (Oct 00 - Sep 02)
3	Identify the names of the contingencies in which function personnel participated during the time frame specified in Step 2 and the associated periods of deployment. **NOTE**: Do not include contingencies where workload reduced at the home station as a result of deployment actions. For example, if a supply unit deploys personnel with their Mobag commitment, the workload went with them, reducing home station workload. No contingency credit should be given.	**Contingency** / **Deployment Dates** Contingency 00-6 Nov - Dec 00 Contingency 01-1 Mar - May 01 Classified Contingency Sep - Nov 01
4	For each contingency identified in Step 3, specify	**Contingency** **Deployed Man-days**

	the total number of deployed man-days (one man-day equals one person deployed for one day). Do not include any deployed man-days for personnel deployed with workload from home station. For example, for Fire Protection Flight, do not include any deployed man-days for personnel deployed along with, and assigned to, their own home stations' fire protection vehicles.	Contingency 00-6 120 Contingency 01-1 245 Classified Contingency 193
5	Compute the man-hours lost from the function. Multiply the deployed man-days from Step 4 by the daily man-hour constant of 5.360. This constant reflects the military peacetime MAF times the overload factor (151.5 x 1.077) divided by the average monthly calendar days (30.44). For Fire Protection Flight only, the daily man-hour constant is 9.297 (383/30.440.	<u>Contingency</u> <u>Man-hours</u> Contingency 00-6 (120)(5.360)=643.20 Contingency 01-1 (245)(5.360)=1,313.20 Classified Contingency (193)(5.360)= 1,034.48
6	Sum all of the contingency man-hour values computed in Step 5.	Total Contingency Man-hours = 2,990.88
7	Compute the average monthly man-hours for a function's contingency participation by dividing the man-hour total found in Step 6 by the number of months for which data is reported (Step 2).	$\frac{2{,}990.88}{24} = 124.62$
8	Divide the calculated monthly man-hours found in Step 7 by 163.2 to obtain fractional manpower.	$\frac{124.62}{163.2} = .7636$

2.3.12. Step 12. Add the results from paragraphs **2.3.10**, and **2.3.11** to the result in paragraph **2.3.9** to obtain total fractional manpower. Round up to the next whole manpower value. Convert the manpower into man-hours and use AFI 38-201, Table **2.2** to guide application procedures. Refer to **Attachment 3**, Manpower Table for skill and grade.

3. Statement of Conditions. This flight's normal hours of operation are 24-hours-a-day, 7-days-a-week. No environmental or physiological factors were identified that had a manpower impact on this flight.

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Commander, Air Force Manpower and
Innovation Agency

STANDARD MANPOWER TABLE

WORK CENTER/FAC			APPLICABILITY MAN-HOUR RANGE								
FUELS MANAGEMENT FLIGHT/41D1			Extrapolation Limits Not Used								
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Supply Mgmt Officer	23S4	MAJ	1	1	1	1	1	1	1	1	1
Supply Operations Officer	23S3	CPT									
Fuels Manager	2F000	CMS	1	1	1	1	1	1	1	1	1
Fuels Superintendent	2F091	SMS	1	1	1	1	1	1	1	1	1
Fuels Craftsman	2F071	MSG	8	8	8	8	8	8	8	8	8
Fuels Craftsman	2F071	TSG	13	13	13	13	13	14	14	14	14
Fuels Journeyman	2F051	SSG	25	25	25	25	25	25	25	25	25
Fuels Journeyman	2F051	SRA	35	35	35	35	36	36	36	37	37
Fuels Apprentice	2F031	AIC	32	33	34	35	35	35	36	36	37
Information Mgmt Journeyman	3A051	SSG	1	1	1	1	1	1	1	1	1
Information Mgmt Journeyman	3A051	SRA	1	1	1	1	1	1	1	1	1
TOTAL			118	119	120	121	122	123	124	125	126
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Supply Mgmt Officer	23S4	MAJ	1	1	1	1	1	1	1	1	1
Supply Operations Officer	23S3	CPT									
Fuels Manager	2F000	CMS	1	1	1	1	1	1	1	1	1
Fuels Superintendent	2F091	SMS	1	1	1	1	1	1	1	1	1
Fuels Craftsman	2F071	MSG	8	8	8	8	8	8	8	8	8
Fuels Craftsman	2F071	TSG	14	14	14	14	14	14	14	14	14
Fuels Journeyman	2F051	SSG	25	25	25	25	25	25	25	25	25
Fuels Journeyman	2F051	SRA	37	38	38	38	38	39	39	39	40
Fuels Apprentice	2F031	AIC	38	38	39	40	41	41	42	43	43
Information Mgmt Journeyman	3A051	SSG	1	1	1	1	1	1	1	1	1
Information Mgmt Journeyman	3A051	SRA	1	1	1	1	1	1	1	1	1
TOTAL			127	128	129	130	131	132	133	134	135

AF Form 1113, JUN 91 (COMPUTER GENERATED). PREVIOUS EDITION IS OBSOLETE.

Attachment 4

VARIANCES

FUELS MANAGEMENT FLIGHT

A4.1. Title. Positive Mission Variance for Cryogenics Production Plants.

A4.1.1. Definition. Additional manpower required to operate cryogenics production facilities.

A4.1.2. Impact and Applicability.

Table A4.1. Man-hour Impact

LOCATON	MAN-HOUR IMPACT
Kadena AB	+2121.6
Kunsan AB	+1958.4
Lajes AB	+1142.4
Misawa AB	+1958.4
Osan AB	+1958.4

A4.2. Title. Positive Mission Variance for Cryogenics Maintenance and Distribution.

A4.2.1. Definition. Additional manpower required to maintain and distribute cryogenics.

A4.2.2. Impact and Applicability.

Table A4.2. Man-hour Impact

LOCATION	MAN-HOUR IMPACT
Elmendorf AFB	+701.76
Travis AFB	+347.6
Dover AFB	+347.6

A4.3. Title. Positive Environmental Variance for Snow Removal.

A4.3.1. Definition. Additional manpower required for removal of snow from the lateral control pits.

A4.3.2. Impact and Applicability.

Table A4.3. Man-hour Impact.

LOCATION	MAN-HOUR IMPACT
Eielson AB	+229

Attachment 5

PROCESS ANALYSIS SUMMARY

FUELS MANAGEMENT FLIGHT

Table A5.1. PROCESS ANALYSIS SUMMARY, FUELS MANAGEMENT FLIGHT

PROCESS TITLE (In Priority Order)	PROCESS TIME (Avg Mthly MHRS)
1. Fuels Management	326.4
6. Fuel Product Distribution	2677.51
3. Fuel Product Receiving	1535.59
13. Resource Control Center	2284.8
16. Standby Time for Peak Workload	2976.761
10. Petroleum, Oil, Lubricants (POL) System Maintenance	592.52
4. Product Closeout	180.80
9. Petroleum, Oil, Lubricants (POL) System Inspection	370.65
8. Checkpoint Operation	652.8
5. Quality Control and Inspection	652.8
7. Fuels Flight Support	326.4
11. Environmental Protection	32.43
12. Confined Space Entry	81.97
14. Security Check	83.30
15. Travel to and from Location	705.59
2. Fuels Administration	163.2

NOTE: The processes are listed in order of decreasing priority

BY ORDER OF THE
SECRETARY OF THE AIR FORCE

AFMS 42B1
22 AUGUST 2003

Manpower Standard

★ *VEHICLE MAINTENANCE*

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OPR: AFMRDS/RDB (MSgt Mitch Kuhl) Certified by: AFMRDS/CD (Mr. J. McDaniel, III)
Supersedes AFMS 42B1, 15 June 1994 Pages: 53
Distribution: F

This Air Force Manpower Standard (AFMS) quantifies the manpower required to accomplish the tasks described in the process oriented description (POD) for varying levels of workload. The mission objective of the Vehicle Maintenance (VM) Flight is to: perform vehicle and equipment maintenance, perform maintenance support, control and manage Contractor-Operated Parts Store/Blanket Purchase Agreement (COPARS/BPA) or similar functions, and perform non-registered nonprogrammable vehicle and equipment maintenance. This standard defines the manpower required to support a Vehicle Maintenance Flight at Air Mobility Command, Air Combat Command, United States Air Forces Europe, Air Force Materiel Command, Air Education and Training Command, Air Force Space Command, Air Force Special Operations Command, and Pacific Air Forces bases. It applies to peacetime operations only. It does not apply to Air National Guard and Air Force Reserve bases. This standard does not apply to elements that have been cost compared (OMB Circular A-76). This standard does not apply to Brooks AFB due to city-base concept and Hickam AFB due to the logistic consolidation under reengineering, and any vehicle maintenance flight with Vehicle Equivalents (VEs) less than 775. AFI 24-302, *Vehicle Maintenance Management,* and AFMAN 24-307, *Procedures for Vehicle Maintenance Management,* contain United States Air Force (USAF) policy and procedural guidance for the Vehicle Maintenance Flight. This AFMS has been developed in accordance with policy and guidance from AFI 38-201, *Determining Manpower Requirements*, and AFMAN 38-208, *Air Force Management Engineering Program (MEP)*. Send comments and suggested improvements on AF Form 847, **Recommendation for Change of Publication**, through channels, to AFMRDS/RDB, 550 E Street East, Randolph AFB TX 78150-4451. A glossary of references and supporting information is at **Attachment 1.**

SUMMARY OF REVISIONS

This standard is substantially revised and must be completely reviewed. All processes and variances for the VM Flight were reviewed and reengineered in accordance with FY00-05, *Annual Planning and Programming Guidance (APPG)*. Revision of the man-hour equation was based on a revalidation of workload and processes. Staffing patterns for VM management, Maintenance Control and Analysis (MC&A), and Materiel Control were used. An approved

initiative to merge Fleet Management from Vehicle Operations (AFMS 42A1) to VM has been incorporated with this AFMS. Other approved initiatives will be incorporated into this AFMS as they are implemented. Man-hour credit for non-Aerospace Expeditionary Force (AEF) contingency deployments (excluding Operations ENDURING FREEDOM and NOBLE EAGLE), exercise participation, and exercise support is included in this AFMS as variances. AEF authorizations have already been placed at specific bases.

1. Standard Data.

1.1. Approval Date.

1.2. Man-hour Data Source. Per accomplishment times (PAT) were collected from subject matter experts (SMEs) via workshop measurement for Customer Service, General Purpose Vehicles and Equipment, Special Purpose Vehicles and Equipment, Material Handling Equipment (MHE), 463L Vehicles, Equipment, Fire Department Vehicles and Equipment, Refueling Unit Vehicles and Equipment, and Allied Trades. Workload from other areas (tire shop, mobile maintenance, electrical shop, etc.) was included in one of the seven areas listed in prior sentence. Frequencies for these areas were obtained from On-Line Vehicle Interactive Management System (OLVIMS). A staffing pattern was developed for MC&A, Materiel Control, and VM Management. Environmental Management, Technical Order (TO), Commercial Manual Library and Training were measured via operational audit, and the frequencies came from manual counts. Contingency has been credited using variances to capture credit at each specific location instead of part of manpower equation.

1.3. The man-hour equation applies to all VM activities except VM management, MC&A, and Materiel Control, which are covered under staffing patterns. **Y = 4.6349X - 1513.41**

1.4. Workload Factor (X).

1.4.1. Title. A Vehicle and/or Equipment Equivalent (VE) Assigned.

1.4.2. Definition. The total number of vehicle and/or equipment equivalents assigned that Vehicle Maintenance is responsible for maintaining regardless of owning command or using activity. Do not include "M" coded War Reserve Material (WRM) assets. Major command (MAJCOM)-developed variances will be built to account for this workload. ***NOTE:*** Some WRM vehicle types are not placed in storage because of the potential degradation of components, due to lack of use. These are referred to as Integrated WRM, and their workload must be included when computing manpower. MAJCOM WRM variances must address WRM in storage, as well as Integrated WRM. ***NOTE:*** When pricing out the standard, Eielson AFB should not include assigned VEs from Blair Lakes in workload. Support for Blair Lakes to include maintenance of vehicles is included in the variance for site support.

1.4.3. Source. Vehicle Master List (A), PCN SB004-023, last page total. For WRM exclusion, count all vehicle equivalents associated with "M" coded assets listed in WRM indicator column and subtract from last page total. Obtain 12 months' worth of data. If there is a difference in the vehicle equivalents of greater than 100 between any 2 months in that 12-month period, provide an explanation for the variation. VM personnel will research and provide this explanation and determine if variation is representative of current workload. If variation is considered representative, include workload in calculations. If the variation is not considered representative, do not include workload and previous months' workload in calculations, as it would not be considered representative. One example of data not being representative would be a

VM flight losing numerous VEs because of conversion to General Services Agency (GSA)-leased vehicles and not performing maintenance on them. Another example could be the addition or deletion of a squadron from a base that could increase or decrease VEs by 100. ***NOTE:*** An agreement between GSA and some VM flights allows for VM to perform maintenance on GSA-leased vehicles. This agreement allows GSA VEs to be included in their workload factor (WLF) computations.

1.5. Manpower Staffing Patterns.

1.5.1. Manpower Staffing Pattern for Vehicle Maintenance Management. Based on the number of personnel authorized, staffing is as follows:

Table 1.1. Vehicle Maintenance Management Staffing Pattern.

VM Flight	VM Management		
Population Range	Grade	AFSC	Requirement
0 - 65	SSG	3A051 or 2T35X	1
	SMS	2T390	1
66 - 89	SSG	3A051or 2T35X	1
	CMS	2T300	1
90 -121	SSG	3A051 or 2T35X	1
	SMS	2T390	1
	CMS	2T300	1
122 and above	SSG	3A051 or 2T35X	1
	MSG	2T37X	1
	SMS	2T390	1
	CMS	2T300	1

1.5.2. Manpower Staffing Patterns for MC&A. Staffing patterns reflect the two disciplines with MC&A: Fleet Management (Table 2) and MC&A (Table 3):

Table 1.2. MC&A Staffing Pattern (Fleet Management).

Total Authorized Vehicles (not VEs) on MAJCOM Vehicle Authorization Listing (VAL)	Maintenance Control & Analysis
Authorized Vehicle Range	**Requirement**
0 – 249	1
250 – 549	2
550 – 1249	3
1250 - 1999	4
2000 - 2499	5
2500 - 3000	6

Table 1.3. MC&A Staffing Pattern.

Total Assigned Vehicles (VEH), not VEs, from Vehicle Master List (A), PCN SB004-023	Maintenance Control & Analysis
Assigned Vehicle Range	**Requirement**
0 – 249	2
250 – 349	3
350 – 449	4
450 - 599	5
600 - 749	6
750 - 949	7
950 - 1249	8
1250 -1599	9
1600 - 1799	10
1800 - 1999	11
2000 - 2199	12
2200 - 2499	13
2500 - 2749	14
2750 - 3000	15

NOTE: When collecting 12 months' worth of data, if there is a difference of 50 +/- assigned vehicles, explain reason. Depending on reason, may need to disregard previous months if they are no longer considered representative.

Table 1.4. MC&A Grade/AFSC Matrix.

Combined Manpower Earned	Grade AFSC	Grade AFSC	Grade AFSC	Grade AFSC	Grade AFSC	Grade AFSC	Total MC&A Requirement
	A1C 2T337	**SrA 2T357**	**SSgt 2T357**	**TSgt 2T377**	**MSgt 2T377**	**SMSgt 2T39X**	
3	0	1	1	1	0	0	3
4	1	1	1	1	0	0	4
5	1	1	2	1	0	0	5
6	1	2	2	1	0	0	6
7	2	2	2	1	0	0	7
8	2	3	2	0	1	0	8
9	2	3	2	1	1	0	9
10	2	3	2	2	1	0	10
11	3	2	3	2	1	0	11
12	3	3	3	2	1	0	12
13	3	4	3	2	1	0	13
14	3	4	3	3	1	0	14
15	3	4	4	3	1	0	15
16	3	5	4	3	1	0	16
17	3	6	4	3	1	0	17
18	4	6	4	3	1	0	18
19	4	6	5	3	1	0	19
20	4	6	5	3	1	1	20
21	5	6	5	3	1	1	21

1.5.3. Manpower Staffing Pattern for Materiel Control. Based on the number of vehicles assigned, staffing is as follows:

Table 1.5. Materiel Control Staffing Pattern.

Total Assigned Vehicles (VEH) from Vehicle Master List (A), PCN SB004-023	Grade AFSC	Grade AFSC	Grade AFSC	Grade AFSC	Grade AFSC	Total Materiel Control
Assigned Vehicle Range	**A1C 2T33X/ 2S031**	**SrA 2T35X/ 2S051**	**SSgt 2T35X/ 2S051**	**TSgt 2T37X/ 2S071**	**MSgt 2T37 X/2S0 71**	**Requirement**
0 - 299	0	1	1	0	0	2
300 - 499	0	1	1	1	0	3
500 - 799	1	1	1	1	0	4
800 - 999	1	2	1	1	0	5
1000 - 1399	1	2	2	0	1	6
1400 - 1799	2	2	2	0	1	7
1800 - 2199	2	2	2	1	1	8
2200 - 2699	2	3	2	2	1	9
2700 and up	2	3	3	1	1	10

NOTE: Option of Vehicle Maintenance Manager (VMM)/Vehicle Maintenance Supervisor (VMS) to determine ratio between AFSC 2T3XX/2S0X1.

1.6. Points of Contact.

1.6.1. Functional Representative. Lt Col Steven Amato, HQ USAF/ILTV

1.6.2. AFMRDS Representatives. MSgt Mitch Kuhl and Ms Lenise Humble, AFMRDS/RDB

2. Application Instructions.

2.1. Step 1. Compute equation. Obtain total vehicle and/or equipment equivalents minus WRM for the base and substitute for X in the equation. Calculate the equation and the result is earned man-hours.

2.2. Step 2. Determine variance man-hours. **Attachment 4** lists all approved variances. Using this list, identify additional variance man-hours. Add man-hours to the result from Step 1. The man-hour figure is the total earned man-hours from the equation and variances.

2.3. Step 3. Subtract approved contract manpower equivalent (CME) man-hours to determine total in-service man-hours. Multiply the number of applicable CMEs by civilian Man-hour Availability Factor (MAF). Subtract man-hours from Step 2. The result is total in-service man-hours. Do not subtract COPARS and WRM CMEs or any other CME workload not covered by the standard.

2.4. Step 4. Determine required military positions in maintenance shops and deduct from man-hours in Step 3. Do not include MC&A, Materiel Control, or VM Management. Take required military positions and multiply by the military MAF times the overload factor. Subtract from the man-hours in Step 3. Result is total civilian man-hours.

2.5. Step 5. If applicable, determine the required Foreign National (FN) civilian positions in maintenance shops. Convert to FN man-hours by multiplying by appropriate MAF. Do not use an overload factor for FN civilians. Subtract man-hours from Step 4.

2.6. Step 6. Determine United States Direct Hire (USDH) civilian positions. If remaining man-hours from Step 5 are less than 949.91 for Continential United States (CONUS) locations or 995.15 for overseas locations, divide by the product of the appropriate USDH civilian MAF and overload factor. Round up to the next whole number. If remaining man-hours are equal to or exceed 949.91 for CONUS locations or 995.15 for overseas locations, divide by the appropriate civilian MAF. If the fractional manpower requirement is less than .5, round down to the next whole number. If the fractional manpower is .5 or greater, round up to the next whole number.

2.7. Step 7. Add civilian and military requirements together. This figure is used with **Attachment 3** for skill and grade determination.

2.8. Step 8. Determine requirements for MC&A. Using total authorized vehicles from MAJCOM Vehicle Authorization Listing (VAL) and **Table 2,** determine the fleet workload requirement. Using 12-month average of total assigned vehicles from the Vehicle Master List and **Table 3**, determine MC&A workload requirement. Sum these two figures together to determine the total MC&A requirements. Use **Table 4** for skill and grade determination.

2.9. Step 9. Determine requirements for Materiel Control. Using the 12-month average of total assigned vehicles from the Vehicle Master List and **Table 5**, determine Materiel Control requirements and skill and grade.

2.10. Step 10. Determine VM Management requirement. Sum all earned positions from maintenance shops, MC&A, and Materiel Control. Include any AEF positions that are on Unit Manpower Document (UMD). Use **Table 1** to show requirement and skill and grade determination.

2.11. Step 11. Determine total VM flight requirements. Sum all earned positions from maintenance shops, MC&A, Materiel Control, and VM Management.

3. Statement of Conditions. Standard hours of operation for the VM Flight are 8 hours per day, 5 days per week. Some bases adjust standard hours due to workload.

WILLIAM C. BENNETT, JR., Colonel, USAF
Commander, Air Force Manpower and Innovation Agency

Attachment 3

MANPOWER TABLE

STANDARD MANPOWER TABLE											
WORK CENTER/FAC Vehicle Maintenance/42B1			APPLICABILITY MAN-HOUR RANGE 2087.89 - 23811.87								
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Vehicle Maintenance Crftmn	2T370	MSG	0	0	0	0	0	0	1	1	1
Vehicle Maintenance Crftmn	2T370	TSG	2	2	2	2	2	2	2	2	2
Vehicle Maintenance Jrnymn	2T35X	SSG	4	4	4	5	5	5	5	6	6
Vehicle Maintenance Jrnymn	2T35X	SRA	5	6	7	7	7	8	8	8	9
Vehicle Maintenance Apr	2T33X	A1C	2	2	2	2	3	3	3	3	3
TOTAL			13	14	15	16	17	18	19	20	21
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Vehicle Maintenance Crftmn	2T370	MSG	1	1	1	1	1	1	1	1	1
Vehicle Maintenance Crftmn	2T370	TSG	2	2	2	2	2	3	3	3	3
Vehicle Maintenance Jrnymn	2T35X	SSG	6	7	7	7	8	8	8	8	9
Vehicle Maintenance Jrnymn	2T35X	SRA	10	10	10	11	11	11	12	13	13
Vehicle Maintenance Apr	2T33X	A1C	3	3	4	4	4	4	4	4	4
NOTE: 1: Substitution of a 2A751 machinist for a 2T35X is allowed at bases where a requirement for vehicle parts fabrication exists. *NOTE:* 2: Vehicle Maintenance Management, including administration, MC&A, and Materiel Control, are earned in staffing patterns listed in tables 1 - 5.											
TOTAL			22	23	24	25	26	27	28	29	30

Attachment 5

PROCESS ANALYSIS SUMMARY

VEHICLE MAINTENANCE

Table A5.1. Process Analysis Summary, Vehicle Maintenance.

PROCESS TITLE (In Priority Order)	**PROCESS TIME (MONTHLY MAN-HOURS)**
6. Refueling Vehicle and/or Equipment Maintenance and Repair	498.80
5. Fire Department Vehicle and/or Equipment Maintenance and Repair	466.59
3. Special Purpose (SP) Base Maintenance Vehicle and/or Equipment Maintenance and Repair	1361.01
4. 463L Materiel Handling Equipment (MHE) Vehicle and/or Equipment Maintenance and Repair	513.96
2. General Purpose (GP)Vehicle and/or Equipment Maintenance and Repair	2021.69
8. Maintenance Control & Analysis	1027.20
9. Materiel Control	787.20
12. Vehicle Maintenance Management	355.20
1. Customer Service Activity: SYS CD:43	1426.85
7. Allied Trades (Paint, Body, Upholstery, Machine Shop) Maintenance and Repair	756.97
10. Environmental Management	56.88
11. Technical Order Commercial Manual Library	11.90

NOTE: The reengineering team determined that processes 1 - 12 were all considered priority work. Each process was equally important and one was not greater than another. MAJCOM functional OPRs determined priority under duress. They agreed with the reengineering team that all processes are priority workload. Each day priority may change based on circumstances.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

AFMS 42A1
13 June 1997

Manpower Standard

VEHICLE OPERATIONS FOR INSTALLATIONS WITH FLYING MISSIONS

This Air Force Manpower Standard (AFMS) quantifies the manpower required to accomplish the tasks described in the process oriented description for varying levels of workload. This AFMS identifies the peacetime manpower to support the base mission; manage registered vehicles and maintain fleet records; maintain a central dispatch operation; and manage vehicle licensing and qualification. This standard applies to CONUS and overseas Air Force installations with flying missions in AMC, ACC, PACAF, and USAFE. It also applies to Vandenberg AFB, F. E. Warren AFB, Randolph AFB, and Hurlburt Field. Bases without flying missions, see AFMS 42A2. This standard does not apply to AF Reserve, Air National Guard, or bases that are scheduled for closure. Applicable bases will develop a negative variance to account for the processes not performed, and a positive variance to account for processes not included in this AFMS. This AFMS does not apply to flights that have been cost compared (OMB Circular A-76). Bases should develop negative variances to account for processes not performed or performed by contract, and positive variances for processes performed but not included in the AFMS. AFI 24-301, *Vehicle Operations*, provides USAF policy and procedural guidance for this work center. This standard was developed under an objective flight study in accordance with policy and guidance from the Air Staff and AFMAN 38-208, *Air Force Management Engineering Program (MEP)*. Send comments and suggested improvements on AF Form 847, **Recommendation for Change of Publication**, through channels, to AFCQMI/MQAB, 550 E Street East, Randolph AFB, Texas 78150-4451.

★*SUMMARY OF CHANGES*

This AFMS supersedes AFMS 42A1, 23 May 1996. The following variances were updated by USAFE due to base closure actions and realignments: A3.1, A.3.2, A.3.4, A.3.6, A.3.9, A.3.12, A.3.13, and A.3.14. Variance A3.6, Scott AFB was included for (+3) and MacDill AFB for (+6). Variance A.3.7, Scott AFB was added for (+2). Variance A3.12, Yokota was deleted per note on previous edition. References to proper organization designs were updated with current information. Changes are identified with a star (★).

1. Core Composition. The core composition of this AFMS was developed for a Vehicle Operations Flight to support an objective wing having a population of 3,393 authorizations.

1.1. **Core Flight Manpower Required.** 29

1.2. **Core Range.** 20 - 74

1.3. **Programming Factor(s).** Base Population

2. Standard Data:

2.1. **Approval Date.** May 1996

2.2. **Man-hour Data Source.** Workshop Measurement

2.3. **Man-hour Equation.** Y = 1232.91 + 1.01X

Supersedes AFMS 42A1, 23 May 1996 Certified by: AFCQMI/MQA (Lt Col Rudy K. Bruback)
OPR: AFCQMI/MQAB (Mr. Larry Rose) Pages: 18/Distribution: F

2.4. **Workload Factor:**
2.4.1. **Title.** Base Population
2.4.2. **Definition.** The total number of Air Force military and civilian (funded) authorizations to include Air Force tenant organizations. Exclude contract manpower equivalents (CMEs) and geographically separated units (GSUs).
2.4.3. **Source.** The Unit Manpower Document (UMD), File Part A.

2.5. **Points of Contact:**
2.5.1. **AFCQMI Representative:** AFCQMI/MQAB, SSgt Michael Mirich, DSN 487-5911, ext 3221
2.5.2. **Functional Representative:** HQ USAF/ILTV, MSgt Ron Malone, DSN 227-3371

3. Application Instructions:

3.1. **Step 1.** Determine the authorized base population by summing the projected years' authorized totals in the UMD, File Part A. (Do not count CMEs & GSUs.) ***NOTE:*** Bases listed in variance number 17: Do not include in this step the headquarters population that will be used to determine the impact of variance 17.

3.2. **Step 2.** Using the Man-hour Equation, substitute the base population determined in Step 1 for 'X' and compute the man-hours.

3.3. **Step 3.** Divide the computed man-hours by the applicable Man-hour Availability Factor (MAF) and overload factor (use current rounding rules) to determine the core manpower.

3.4. **Step 4.** Determine variance manpower. Using the applicable variance(s) (see Attachment 3) for your base, add/subtract to or from the manning indicated in the core authorizations determined in Step 3 above. This number will be the authorized strength for the Vehicle Operations Flight.

3.5. **Step 5.** Refer to Attachment 2 for the grades and skill table.

4. Statement of Conditions. Standard hours of operation for Vehicle Operations work centers are 24 hours per day, 7 days per week. Weather conditions may affect driving and response time of dispatches. No other conditions had an impact on the development or application of this determinant. Elimination of the VAUB has been included. This AFMS was developed under the CSAF-directed "no growth policy." The major programming factor, base population, is derived from the UMD, File Part A, and excludes CMEs and GSUs. Application of the workload factor must be adhered to. Any deviation to the application instructions could overstate manpower authorizations Air Force-wide, making this AFMS unusable.

NOTE: Core manning does not include on-base shuttle bus operations.

VICTOR M. HELBLING, Lt Col, USAF
Chief, Systems Integration and Support Division
Air Force Center for Quality and Management Innovation

Attachments
1. Process Oriented Description
2. Standard Manpower Table
3. Approved Variances
4. Process Analysis Summary

STANDARD MANPOWER TABLE

WORK CENTER/FAC			APPLICABILITY MAN-HOUR RANGE								
Vehicle Operations Flight for Installations With Flying Missions/42A1			3214.0 - 20730.3								
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Transportation	24T3	CPT	1	1	1	1	1	1	1	1	1
Vehicle Operation Manager	2T100	CMS									
Vehicle Operation Supv	2T191	SMS	1	1	1	1	1	1	1	1	1
Vehicle Operations Crftmn	2T171	MSG	2	2	2	2	2	2	2	2	2
Vehicle Operations Crftmn	2T171	TSG	2	2	2	2	2	3	3	3	3
Vehicle Oper/Disp Jrnymn	2T151	SSG	6	6	6	7	7	7	7	8	8
Vehicle Oper/Disp Jrnymn	2T151	SRA	12	13	13	13	14	14	14	14	15
Vehicle Oper/Disp Apr	2T131	A1C	13	13	14	14	14	14	15	15	15
Information Mgt Jrnymn	3A051	SSG	1	1	1	1	1	1	1	1	1
TOTAL			38	39	40	41	42	43	44	45	46
AIR FORCE SPECIALTY TITLE	**AFSC**	**GRADE**	**MANPOWER REQUIREMENT**								
Transportation	24T3	CPT	1	1	1	1	1	1	1	1	1
Vehicle Operation Manager	2T100	CMS									
Vehicle Operation Supt	2T191	SMS	1	1	1	1	1	1	1	1	1
Vehicle Operations Crftmn	2T171	MSG	2	2	2	2	2	2	3	3	3
Vehicle Operations Crftmn	2T171	TSG	3	3	3	3	3	3	3	3	3
Vehicle Oper/Disp Jrnymn	2T151	SSG	9	9	9	9	10	10	10	10	11
Vehicle Oper/Disp Jrnymn	2T151	SRA	15	15	16	16	16	17	17	17	17
Vehicle Oper/Disp Apr	2T131	A1C	15	16	16	17	17	17	17	18	18
Information Mgt Jrnymn	3A051	SSG	1	1	1	1	1	1	1	1	1
TOTAL			47	48	49	50	51	52	53	54	55

AF Form 1113, JUN 91 (COMPUTER GENERATED). PREVIOUS EDITION IS OBSOLETE.

PROCESS ANALYSIS SUMMARY

VEHICLE OPERATIONS
FOR INSTALLATIONS WITH FLYING MISSIONS

PROCESS TITLE	PROCESS TIME (MAN-HOURS)	MONTHLY PROJECTED WORKLOAD	FRACTIONAL MANPOWER
Performs Managerial/Administrative duties	482.1	FIXED	3.000
Operates Vehicle Dispatches	1.55	1138 Dispatches	10.976
Manages Registered Equipment	.193	833 Records	1.000
Maintains Vehicle Fleet Records	160.7	FIXED	1.000
Services Vehicle, Performs Operator Care and Equipment Support Operations	12.6	56 Vehicles in Vehicle Operation	4.391
Performs Dispatching Operations (7 days/week, 24 hrs/day)	904.4	MIN MANNING	5.628
Manages Vehicle Licensing and Qualification Program	128.6	------	0.800
Directs Dispatch Operation	160.7	FIXED	1.000
Performs Analysis	32.1	------	0.200
Manages Vehicle Control Program	160.7	FIXED	1.000
	TOTAL FRACTIONAL MANPOWER		28.995

NOTE: The above processes are listed in priority order

Appendix H. FY07 AF Personnel Cost Chart

AFI 65-503	Attachment 32		April 2006
Table A32-2			
Application of Military Standard Composite Rate Acceleration			
	Factors for Fiscal Year 2007		
	BASED ON FY 2007 PRESIDENT'S BUDGET		
	FY07		
			Accelerated
	Standard	Accelerated	Hourly
	Composite	Annual	Pay Rate
	Pay Rate	Pay Rate	(Direct
GRADE	w/PCS (1)	Workyear (2)	Workhour (3)
========	=========	=========	========
OFFICER			
O-10	$235,914	$242,187	$133.20
O-9	$230,409	$236,682	$130.18
O-8	$213,569	$219,842	$120.91
O-7	$193,498	$199,771	$109.87
O-6	$183,363	$189,636	$104.30
O-5	$157,024	$163,297	$89.81
O-4	$136,262	$142,535	$78.39
O-3	$111,827	$118,100	$64.96
O-2	$93,087	$99,360	$54.65
O-1	$69,988	$76,261	$41.94
TOTAL AVERAGE	$122,042	$128,315	$70.57
CADETS	$13,624	$19,897	$10.94
ENLISTED			
E-9	$111,540	$117,813	$64.80
E-8	$95,453	$101,726	$55.95
E-7	$83,964	$90,237	$49.63
E-6	$73,168	$79,441	$43.69
E-5	$63,217	$69,490	$38.22
E-4	$52,376	$58,649	$32.26
E-3	$44,633	$50,906	$28.00
E-2	$41,081	$47,354	$26.04
E-1	$35,661	$41,934	$23.06
TOTAL AVERAGE	$61,189	$67,462	$37.10

Acronyms:

FASCAP	Fast Payback Capital Investment
FY	Fiscal Year
OSD	Office of the Secretary of Defense
PEIC	Productivity Enhancing Capital Investment
PIF	Productivity Investment Fund
PCS	Permanent Change of Station

References/Links:

1. See Tables A26-1, A27-1, A28-1, & A29-1 for average civilian pay.
2. See Table A30-1 OSD acceleration factors.
3. See Tables A19-1/2 and A32-1/2 for military pay.
4. See http://www.dod.mil/dfas for civilian & military pay charts.
5. See OSD website http://www.dod.mil/comptroller/rates/fy2006.pdf for acceleration factors.

Table Description:

These tables provide accelerated military pay rates per hour. Table A32-1 is in FY06 dollars; Tables A32-2 is in FY07 dollars.

Table Uses:

1. STANDARD COMPOSITE PAY RATE W/PCS: These rates account for the pay & benefits (including the medical accrual for Medicare-eligible retirees) of active duty military personnel. Apply these rates to the Military Medical Support and the Military Leave & Holiday Factors from table A30-1 in order to calculate the accelerated annual and hourly pay rates (see items 2 & 3, below).

2. ACCELERATED ANNUAL PAY RATE WORKYEAR: These rates represent the total cost of one full-time military member. Use these rates when estimating the cost of military personnel. These should be used in the costing of full-time positions only.

3. ACCELERATED HOURLY PAY RATE (DIRECT WORKHOUR): These rates represent the hourly cost of one part-time military member. They exclude the cost of lost productivity due to time spent on leave & holiday, as well as time spent in activities other than members' primary duties. Use these rates only when basing cost estimates on time actually worked. Do not apply to full-time positions.

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Business Rules & Assumptions:

1. STANDARD COMPOSITE RATE W/PCS: These rates come from the "ANNUAL COMPOSITE RATE" column in table A19-1/2.

2. ACCELERATED ANNUAL PAY RATE WORKYEAR: These rates are computed by adding the Military Medical Support Factor ($6,273 for both officers & enlisted) to the Military Standard Composite Rate w/PCS.

3. ACCELERATED HOURLY PAY RATE (DIRECT WORKHOUR): These rates are computed by adding the Military Medical Support Factor ($6,273 for both officers & enlisted) to the Military Standard Composite Pay Rate w/PCS and then multiplying the result by a factor of .00055, which is derived by dividing one plus the military leave & holiday factor from table A30-1 (14.785%) by 2087 --- ((1+.14785)/2087). For more information on the Military Medical Support Factor or the Military Leave & Holiday Factor, see table A30-1.

Source Data:

1. Based on FY07 President's Budget.
2. Standard Composite Pay with PCS comes from Table A19-1, FY 2006 Standard Composite Rates by Grade and Table A19-2, FY 2007 Standard Composite Rates by Grade.

Table Notes:

1. Accelerated Annual Pay Rate Work year includes medical support costs for officers and enlisted not included in the standard composite rates, $6,273 for both officers and enlisted. For more information, see table A30-1.

2. Please be advised that the Standard Composite Rates w/PCS includes a Medicare-Eligible Retiree Health Care Accrual of $5,652. This amount must be included in any computation of military personnel costs performed for planning/budgeting purposes, but may not be included in calculations performed for reimbursement purposes. See http://www.defenselink.mil/comptroller/rates/fy2006/2006_k.pdf for more details.

POC:

AFCAA/FMFS – DSN: 222-6017 , Commercial (703) 692-6017

Appendix I. Enumeration of Design Points

Design	Factors			
Point	Shift	Surface Area	Complexity	Fleet Size
1	2	0.5	1.5	1
2	2	0.5	1.5	2
3	2	0.5	1.5	3
4	2	0.5	1.5	4
5	2	0.5	1.5	5
6	2	0.5	1.5	6
7	2	0.5	1.5	7
8	2	0.5	2	1
9	2	0.5	2	2
10	2	0.5	2	3
11	2	0.5	2	4
12	2	0.5	2	5
13	2	0.5	2	6
14	2	0.5	2	7
15	2	0.5	2.5	1
16	2	0.5	2.5	2
17	2	0.5	2.5	3
18	2	0.5	2.5	4
19	2	0.5	2.5	5
20	2	0.5	2.5	6
21	2	0.5	2.5	7
22	2	2	1.5	1
23	2	2	1.5	2
24	2	2	1.5	3
25	2	2	1.5	4
26	2	2	1.5	5
27	2	2	1.5	6
28	2	2	1.5	7
29	2	2	2	1
30	2	2	2	2
31	2	2	2	3
32	2	2	2	4
33	2	2	2	5
34	2	2	2	6
35	2	2	2	7
36	2	2	2.5	1
37	2	2	2.5	2
38	2	2	2.5	3
39	2	2	2.5	4
40	2	2	2.5	5
41	2	2	2.5	6
42	2	2	2.5	7
43	2	2.5	1.5	1
44	2	2.5	1.5	2
45	2	2.5	1.5	3
46	2	2.5	1.5	4
47	2	2.5	1.5	5
48	2	2.5	1.5	6
49	2	2.5	1.5	7
50	2	2.5	2	1

Design	Factors			
Point	Shift	Surface Area	Complexity	Fleet Size
51	2	2.5	2	2
52	2	2.5	2	3
53	2	2.5	2	4
54	2	2.5	2	5
55	2	2.5	2	6
56	2	2.5	2	7
57	2	2.5	2.5	1
58	2	2.5	2.5	2
59	2	2.5	2.5	3
60	2	2.5	2.5	4
61	2	2.5	2.5	5
62	2	2.5	2.5	6
63	2	2.5	2.5	7
64	3	0.5	1.5	1
65	3	0.5	1.5	2
66	3	0.5	1.5	3
67	3	0.5	1.5	4
68	3	0.5	1.5	5
69	3	0.5	1.5	6
70	3	0.5	1.5	7
71	3	0.5	2	1
72	3	0.5	2	2
73	3	0.5	2	3
74	3	0.5	2	4
75	3	0.5	2	5
76	3	0.5	2	6
77	3	0.5	2	7
78	3	0.5	2.5	1
79	3	0.5	2.5	2
80	3	0.5	2.5	3
81	3	0.5	2.5	4
82	3	0.5	2.5	5
83	3	0.5	2.5	6
84	3	0.5	2.5	7
85	3	2	1.5	1
86	3	2	1.5	2
87	3	2	1.5	3
88	3	2	1.5	4
89	3	2	1.5	5
90	3	2	1.5	6
91	3	2	1.5	7
92	3	2	2	1
93	3	2	2	2
94	3	2	2	3
95	3	2	2	4
96	3	2	2	5
97	3	2	2	6
98	3	2	2	7
99	3	2	2.5	1
100	3	2	2.5	2

Design	Factors			
Point	Shift	Surface Area	Complexity	Fleet Size
101	3	2	2.5	3
102	3	2	2.5	4
103	3	2	2.5	5
104	3	2	2.5	6
105	3	2	2.5	7
106	3	2.5	1.5	1
107	3	2.5	1.5	2
108	3	2.5	1.5	3
109	3	2.5	1.5	4
110	3	2.5	1.5	5
111	3	2.5	1.5	6
112	3	2.5	1.5	7
113	3	2.5	2	1
114	3	2.5	2	2
115	3	2.5	2	3
116	3	2.5	2	4
117	3	2.5	2	5
118	3	2.5	2	6
119	3	2.5	2	7
120	3	2.5	2.5	1
121	3	2.5	2.5	2
122	3	2.5	2.5	3
123	3	2.5	2.5	4
124	3	2.5	2.5	5
125	3	2.5	2.5	6
126	3	2.5	2.5	7

Appendix J. Regression Analysis

All Factors

Design Point	Y	X1	X2	X3	X4
3,L,H,4	1096	3	0.5	2.5	4
3,L,C,4	871	3	0.5	1.5	4
2,C,H,2	470	2	2	2.5	2
3,H,H,3	1102	3	2.5	2.5	3
2,L,C,3	451	2	0.5	2	3
3,C,H,1	363	3	2	2.5	1
3,C,L,6	1236	3	2	1.5	6
3,C,C,6	1636	3	2	2	6
3,C,H,6	2039	3	2	2.5	6
2,C,L,6	832	2	2	1.5	6
2,C,C,6	1087	2	2	2	6
2,C,H,6	1362	2	2	2.5	6
2,L,L,1	710	2	0.5	1.5	1
2,L,L,6	143	2	0.5	1.5	6
3,L,L,6	992	3	0.5	1.5	6
3,H,H,6	2173	3	2.5	2.5	6
2,C,C,1	208	2	2	2	1
2,C,C,2	376	2	2	2	2
2,C,C,3	560	2	2	2	3
2,C,C,4	725	2	2	2	4
2,C,C,5	917	2	2	2	5
2,C,C,6	1087	2	2	2	6
2,C,C,7	1269	2	2	2	7
3,C,C,1	296	3	2	2	1
3,C,C,2	559	3	2	2	2
3,C,C,3	832	3	2	2	3
3,C,C,4	1088	3	2	2	4
3,C,C,5	1367	3	2	2	5
3,C,C,7	1903	3	2	2	7
3,C,L,1	226	3	2	1.5	1
3,C,L,2	428	3	2	1.5	2
3,C,L,3	631	3	2	1.5	3
3,C,L,4	832	3	2	1.5	4
3,C,L,5	1037	3	2	1.5	5
3,C,L,7	1444	3	2	1.5	7

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.90
R Square	0.81
Adjusted R Square	0.79
Standard Error	251.31
Observations	41.00

ANOVA

	df	*SS*	*MS*
Regression	4	9996391.36	2499097.84
Residual	36	2273651.42	63156.98
Total	40	12270042.78	

	F	*Significance F*
Regression	39.5696	1.03925E-12
Residual		
Total		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1941.76	308.62	-6.29	0.00
X Variable 1	354.63	84.03	4.22	0.00
X Variable 2	66.77	76.20	0.88	0.39
X Variable 3	483.48	106.78	4.53	0.00
X Variable 4	217.02	19.97	10.87	0.00

	Lower 95%	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2567.67	-1315.84	-2567.67	-1315.84
X Variable 1	184.21	525.05	184.21	525.05
X Variable 2	-87.78	221.32	-87.78	221.32
X Variable 3	266.92	700.04	266.92	700.04
X Variable 4	176.51	257.53	176.51	257.53

Y = 354.63(shift) + 66.77(surface area) + 483.48(complexity) + 217.02(fleet size) - 1941.76

Excluding Surface Area

Y	X1	X3	X4
1096	3	2.5	4
871	3	1.5	4
470	2	2.5	2
1102	3	2.5	3
451	2	2	3
363	3	2.5	1
1236	3	1.5	6
1636	3	2	6
2039	3	2.5	6
832	2	1.5	6
1087	2	2	6
1362	2	2.5	6
710	2	1.5	1
143	2	1.5	6
992	3	1.5	6
2173	3	2.5	6
208	2	2	1
376	2	2	2
560	2	2	3
725	2	2	4
917	2	2	5
1087	2	2	6
1269	2	2	7
296	3	2	1
559	3	2	2
832	3	2	3
1088	3	2	4
1367	3	2	5
1903	3	2	7
226	3	1.5	1
428	3	1.5	2
631	3	1.5	3
832	3	1.5	4
1037	3	1.5	5
1444	3	1.5	7
363	3	2.5	1
696	3	2.5	2
1035	3	2.5	3
1366	3	2.5	4
1710	3	2.5	5
2378	3	2.5	7

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.90
R Square	0.81
Adjusted R Square	0.80
Standard Error	250.52
Observations	41.00

ANOVA

	df	*SS*	*MS*
Regression	3	9947904.18	3315968.06
Residual	37	2322138.60	62760.50
Total	40	12270042.78	

	F	*Significance F*
Regression	52.84	0.00
Residual		
Total		

		Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept		-1913.36	305.95	-6.25	0.00
X Variable 1	Shifts	365.41	82.86	4.41	0.00
X Variable 2	Complexity	513.15	100.95	5.08	0.00
X Variable 3	Fleet Size	217.95	19.88	10.96	0.00

		Lower 95%	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept		-2533.28	-1293.45	-2533.28	-1293.45
X Variable 1	Shifts	197.51	533.30	197.51	533.30
X Variable 2	Complexity	308.60	717.70	308.60	717.70
X Variable 3	Fleet Size	177.66	258.23	177.66	258.23

Y = 365.41(shift) + 513.15(complexity)+217.95(fleet size)-1913.36

		Coefficients	*P-value*
Intercept		-1913.36	0.00
X Variable 1	Shifts	365.41	0.00
X Variable 2	Complexity	513.15	0.00
X Variable 3	Fleet Size	217.95	0.00
R Square	0.81		

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14. ABSTRACT

Successful space-based technologies like satellite imagery and GPS have increased military demand for a rapid-response launch capability. AF Space Command's Operationally Responsive Spacelift program was developed to ensure that the AF has the capability to launch a payload into orbit within hours of a tasking notification, and requires development of a new space launch vehicle. The Reusable Military Launch Vehicle (RMLV) is currently in the design phase. The AF Research Laboratory sponsored development of the MILEPOST simulation model in order to assess the turnaround time, and thus responsiveness, of various design alternatives. The focus of this thesis is to improve the fidelity of the MILEPOST model by assessing the logistics manpower required to support the modeled turnaround activities.

The research determined the appropriate AF organizational structure and manpower requirements for RMLV ground support agencies based on the activities modeled in MILEPOST. This information will be incorporated into the model in future research efforts, resulting in the capability to evaluate RMLV design alternatives based on both turnaround time and workforce requirements.

15. SUBJECT TERMS

Reusable Launch Vehicle, Hybrid Launch Vehicle, Logistics Support, Logistics Manpower, Maintenance Manpower, Manpower Requirements, Turnaround Time, Regeneration, Ground Support Operations

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